Proceedings

ISWS Golden Jubilee International Conference

on

"Weeds and Society: Challenges and Opportunities"

21-24 November 2018
Jabalpur, India

Supported by

NABARD

Organized by

Indian Society of Weed Science

In collaboration with

Indian Council of Agricultural Research

ICAR - Directorate of Weed Research

Citation: Proceedings of ISWS Golden Jubilee International Conference on "Weeds and Society: Challenges and Opportunities", 21-24 November 2018, ICAR-DWR, Jabalpur, Indian Society of Weed Science, India. 428 p.

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Cover page Photographs (Left to Right)

A water channel severely infested with water hyacinth; *Phalaris minor* infestation in a wheat field; Invasion of *Mikania micrantha* on trees in forest

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PREFACE

Weeds are the major agricultural pests that can devastate a crop if not properly managed. Losses caused by weeds in the developing world are still at least 37% annually and in certain regions, losses can be up to 90-95% including total crop failure. In addition to direct effect on crop yield, weeds result in considerable reduction in input-use efficiency, and adversely affect biodiversity, animal health and environmental security. The problem of weeds is as old as the agriculture itself as almost all crop plants have been domesticated from their wild relatives only. Despite the development of weed management technologies, the weed related problems have been virtually increasing due to adoption of modern cultivation methods, and the threats posed by climate change, globalization, herbicide resistance development in weeds and commercialization of herbicide-tolerant crops.

Over the years, the discipline of weed science has also developed in many countries of the region and professional societies dealing with the subject have been established for mutual exchange and sharing of knowledge. The Indian Society of Weed Science (ISWS), established in 1968, promotes research, education, and extension outreach activities related to weeds; provides science-based information to the public and policy makers; create awareness of weeds and their impacts on managed and natural ecosystems in the country. Besides organizing various activities including conferences and symposia at the national level, the Society has also been providing a platform for sharing of international experiences on emerging issues in weed science. On completion of its 50 years of journey, the Society is organizing ISWS Golden Jubilee International Conference at Jabalpur during 21-24 November, 2018 with a theme "Weeds and Society: Challenges and Opportunities".

On the special occasion of the ISWS Golden Jubilee International Conference being organized at Jabalpur, India during 21-24 November, 2018, a series of publications were brought out on the status of weed science research in the country. This compilation includes abstracts of Keynote address (1), Plenary presentations (7), Lead presentations (22), Oral presentations (107) and Poster presentation (292). The members of the publication committee (Drs. Ashok Yadav, PP Choudhary, Yogita Gharde, SP Singh, VK Choudhary, Ramanjit Kaur, JP Deshmuks and Simarjit Kaur,) and Convener, Dr. RP Dubey under the Chairmanship of Dr. JS Mishra, have undertaken the voluminous task of compiling, editing and presenting these articles in a systematic manner. It is hoped that this volume will be useful to scientists, teachers, students, administrators and policy makers who are concerned with weed management in respective countries.

The financial assistance received from Research and Development Fund of National Bank for Agriculture and Rural Development (NABARD) towards this publication is gratefully acknowledged.

21 November, 2018

Dr. V.P. Singh
President, ISWS

Dr. Sushilkumar
Organizing Secretary

ACKNOWLEDGEMENTS

Publication Committee of the ISWS Golden Jubilee International Conference is pleased to present the ABSTRACTS of e-Proceedings containing the keynote lecture, presidential lecture, plenary lectures, lead lectures, and oral & poster presentations submitted by the weed scientists for presentation at ISWS Golden Jubilee International Conference on “Weeds and Society: Challenges and Opportunities” being organized at ICAR-Directorate of Weed Research Jabalpur from 21-24 November, 2018. A large number of papers were received covering a wide range of themes from all over India and a few from abroad. These papers were thoroughly reviewed for both technical content and editorial quality.

The papers were reviewed by the members of the committee and others invited for both technical content and editorial quality. Additionally, the editors were requested to grade the papers for their quality so that priority could be given for higher quality papers for oral presentations. Given the large number of papers received and the short time period available, most of the reviewers completed the process of editing meticulously and on time. Some of the senior editors worked tirelessly always willing to take extra load and volunteering to complete the process of editing in a very short time period.

The Publication Committee noted that though the papers, in general, covered the main theme of the Conference well, the number of papers on weed control in individual field crops far outnumber than those on other sub-themes. Further, papers on chemical weed control / herbicides are many but very few papers focused on other control measures and habitat management approaches in integrated cropping/farming systems. The papers on other relevant sub-themes, such as economics, ecology, weed utilization, weed science education, participatory research are also minimal. It is hoped that some of these neglect areas/gaps would be addressed adequately during the Symposia and lead/plenary paper presentations. It was noted that large number of papers clearly highlighted the role of weed science in contributing to agricultural productivity. However, only a few papers focusing on other developmental challenges as biodiversity conservation, environmental degradation and climate change were received indicating that weed science addressing these global challenges is yet to be intensified in the Asian–Pacific region.

We thank Dr. V.P. Singh, President, ISWS and Dr. Sushil Kumar, Secretary, ISWS and Organizing Secretary of this Golden Jubilee International Conference for giving us this opportunity and providing their guidance and inputs for bringing out this proceeding. We also thank all the authors for contributing research articles for presentation at this Conference. We appreciate the efforts made by Mr. Gyanendra Pratap Singh and Mr. Sumit Gupta in processing, and formatting of articles, and bringing out the proceedings in a record time.

21 November, 2018

Publication Committee
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Keynote address and Plenary lectures

Intractable weed problems need innovative solutions using all available technologies

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There are a growing number of seemingly intractable weed problems that are globally prevalent on a large scale. The present solutions are often not realistic solutions, as they may include compromises such as lower yield, more costly or expensive herbicides, or more environmentally-degrading cultivations, growing alternative less effected but lower yielding varieties or other crop species that are less appropriate. Innovative solutions may be out there already, or can be conceived and tested but are not. Because too many weed scientists feel uncomfortable when out of the box, lack the basic knowledge on which to base innovation and/or are reluctant to collaborate with colleagues in other areas who could assist, as well as the many that fear the wrath of detractors who view innovation as a threat. There is often strong public dissent to innovations, typically fanned by those who lose out economically, but the reasons they promulgate are not economic and are targeted to public emotions. Agriculture has some problems that have been intractable to present technologies and we have no choice but to utilize new technologies to overcome them. These include developing new herbicides that affect multiple targets, new selective synergists and safeners, transgenic herbicide resistant plants that will not have the transgenes expressed in related weeds, using transposons to disseminate deleterious genes in weeds, sterile pollen, enhanced-virulence biocontrol agents with sustaining formulations. These might be workable for multiple resistant *Amaranthus* and *Echinochloa* species, parasitic weeds, *Phalaris* in wheat as well as weedy rice in rice. Per force, most of the innovations must originate in the public sector, by weed scientists who have a broad training in basic sciences, in collaboration with experts from other fields. There has never been an agricultural innovation that has been sustainable forever. They all have and will have problems because weeds evolve. Let us remember that the green revolution was predicated on having adequate methods of selective weed control. If not for these chemicals, breeders would still be breeding taller and taller wheat and rice, ignoring that the weeds co-evolve to be taller and taller.

Ecological principles can help with weed management decisions

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Should the discipline of Weed Science be viewed as branch of Plant Ecology? I will argue that the answer to this question should be 'yes' and that an understanding of ecological principles is essential for designing sustainable weed management strategies. In addition, crop fields represent a highly controlled model system for challenging ecological theory and, therefore, present an opportunity to reach a wider audience with our work. I present four worked examples to support this argument.

Firstly, I apply principles of functional ecology to demonstrate how agriculture has selected for a functionally distinct subset of weedy plants from wider national floras and how management change further filters weed community traits. The regular disturbance and high fertility of cropped fields has selected for species with extreme ruderal strategies characterised by high specific leaf area, early flowering and long flowering duration. Within this group of weedy plants, agricultural intensification has filtered out species adapted to intermediate levels of soil fertility characterised by a relatively large seed, later flowering and short stature (a 'rare weed trait syndrome').Understanding the functional response of weed communities to management will potentially lead to generic principles that can be applied to environments with different species pools.

Secondly, I present an analysis of the effect of the environment on inter and intra specific competition in the context of understanding plant co-existence and the impact of climate change. By analysing temporal dynamics of functionally equivalent pairs of weeds on the Broadbalk long term winter wheat experiment (for example *Papaver rhoeas* and *Tripleurospermum inodorum*), we demonstrated contrasting responses to environmental variability. In the case of *P. rhoeas* and *T*. inodorum, *P. rhoeas* grew better at lower temperatures and was more dominant in cool springs. As well as supporting coexistence, the results also have implications for future weed community dynamics under climate change. This example also demonstrates the importance of long term experiments and data to understanding the interactions of management and the environment on weeds.

Thirdly, I explore the importance of maintaining weed diversity for sustainable weed control and as an indicator of the sustainability of the whole cropping system. Spatial and temporal homogenisation of cropping landscapes at multiple scales has led to the selection of fewer pernicious weed species that are highly adapted to the current management template. I develop the hypotheses that a more diverse weed community is less competitive in any given crop because of niche differentiation and that diversity of the weed seed bank is a useful indicator of sustainable intensification across multiple criteria (including yield stability and soil health) because it reflects overall cropping and management diversity.

Finally, I apply the 'mass effects principle' to weed communities. The mass effects theory predicts that the interface between two contrasting habitats will have a higher species richness than either habitat on its own because of spill-over effects. I show, using a recent analysis, that much of the increased weed diversity observed at the edges of fields in intensively managed crops in the UK can be attributed to spill-over from adjacent habitats. This has implications for conservation schemes aimed at preserving farmland biodiversity, including rare arable weeds.

Conservation agriculture-based resource-conserving practices and weed management in the rice-wheat cropping systems of the Indo-Gangetic Plains

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Conservation agriculture (CA) was used interchangeably with terms like conservation tillage, no tillage, zero tillage (ZT), direct drilling *etc.* ZT has been the function of weed management, not just in wheat but in rice too. ZT in India was at the dead end in the early 1990s. Until the evolution of herbicide resistance (HR) in Phalaris minor. By now ZT machines are recognised not only as a commercial venture but also attracts major technological step towards intensification of agriculture. With the availability of the "Happy Seeder"– a ZT machine that can plant rice and wheat in high-residue conditions – has made it possible to retain the residues on the soil surface, thereby providing an alternative to residue burning. It has been reported that ZT in combination with residue mulch reduced the weed problem over time in ZT wheat than CT wheat. In direct-seeded rice (DSR), no single method can provide effective and sustainable weed management solutions. Therefore, combining cultural methods in tandem with judicious use of modern herbicides is crucial. For successful weed control in DSR, pre-emergence (pendimethaline or oxadiargyl or pretilachlor with safner) followed by post-emergence (bispyribac or bispyribac based tank mixture including bispyribac + pyrazosulfuron/azimsulfuron/ 2,4-D/halosulfuron or fenoxaprop with safner or fenoxaprop based tank mixture including fenoxaprop + ethoxysulfuron) herbicide application has provided effective weed control in DSR.

Fifty years of weed science research in India - Challenges and opportunities

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The weeds menace is as old as agriculture. The total actual economic loss, due to weeds in 10 major crops of India, was estimated at US$ 11 billion. Weed management involves integrated efforts to manage weeds in crops to selectively minimize the weed competition so as to enable crops to optimally use resources such as soil fertility, water and sunlight, for attaining the optimal harvestable crop yield. During the last fifty years researchers have worked, evolved weed management technologies and passed on to farmers through different means by which farmers got benefited. However, weeds continue to be a major problem as weeds are dynamic. Hence, continuous efforts are needed to monitor the ever changing weeds in different ecosystems and develop suitable weed management technologies for varying ecosystems. It is essential to review the research work so far conducted and plan for future weed management research for continuously keeping the crop weed balance in favor of crops. Hence in this paper, a review of the research published in Indian Journal of Weed Science (IJWS) during the last fifty years was analyzed and synthesis is presented in this paper along with future weed management research needs.

Hand weeding and mechanical weed management was the major weed management tools used by the farmers prior to the initiation of research on herbicides in 1948 with 2, 4-D in India. In the initial years of Indian weed management research, researchers focused on herbicide based weed management. Of 333 published papers in IJWS during 1980 to 1989, 69% of papers were on herbicides. The research on herbicides alone decreased with the time and the research on integrated weed management (IWM) increased from 9% (during 1980-89) to 36% (2010 to 2018). However, 39% of the papers are still on herbicides alone and comparing herbicides performance with hand weeding and other methods. Rice and wheat are the major crops researched in the past as well as at present. However, during recent years papers appeared on increased number of crops. The research papers published on cropping systems were 6% during 1980-89 and currently 8% only, of the total published. In recent years, a few papers are published on conservation agriculture and herbicide tolerant crops. Weed ecology papers were below ten percent of the total papers published in IJWS and there is urgent need for increasing the efforts to understand the weeds through studying the ecology and biology for their better management. A few of the areas of weed management research that needs to be focused include: weeds monitoring; bio control; competitive crop cultivars; location specific mechanical tools to integrate with other methods; cropping systems and crop rotations as IWM components; preventive weed management; herbicide resistant weeds; weeds use; parasitic, problematic and aquatic weeds management; herbicides residues; developing simple decision making tools and apps for farmers to manage weeds.

The climate change is a reality and challenge for the Weed Scientists in India to understand impact of climate change on the weeds and weed management and evolve IWM strategies to manage weeds in the changing climate. Vast opportunity exists for weed science researchers to evolve effective, economical and ecologically safe integrated weed management strategies through interdisciplinary research involving disciplines such as biology; ecology; agronomy; physiology; microbiology; genetic engineering; soil science; toxicology; biochemistry; residue chemistry and agricultural engineering.

Why systems approach in weed management?

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Despite concerted efforts for over seventy years by farmers ably supported by the research and development activities promoted by weed scientists and the industry, weeds continue to dominate, even in developed countries that boast of high productivity levels in the world. The Weed Science Society of America estimates that uncontrolled weeds cause about 50% loss in the productivity of corn and soybean, amounting to $ 43 billion annually in USA and Canada. This is primarily due the dominance of herbicide resistant weeds. The problem is aggravated further by the resurgence of weeds resistant to glyphosate in GM crop regime, which is currently being adopted over a phenomenal 190 mha area. The experts believe that glyphosate-resistant weeds present the greatest threat to sustained weed control in major agronomic crops because this herbicide is used to control weeds with resistance to many other herbicides. With no herbicide molecule possessing new site of action in sight in the near future, the situation will only get worse. The developing countries, including India should take note of these developments and make appropriate policy and technological interventions to avoid a situation similar to the one seen in the west.

Weeds are ubiquitous and are known to evolve and survive any attempt to supress them. Weeds are a part of the agricultural ecosystem and all the production practices will impact weeds directly or indirectly. Attempts to control weeds using a single method in single crop cycle would be counter-productive, as they tend to evolve and adopt quickly. A system approach with emphasis on weed seed bank is critical in developing a strategy for management of annual weeds. A good understanding of biology and ecology of few major weeds in the system will further strengthen the efforts. Such an approach based on ecological principles and system concept in mind will ensure management of weeds on a sustainable basis. It is important to frame multi-tactic approach involving relevant preventive and cultural methods with little reliance on herbicides to help the small holder farmers. The overall objective of the approach would be to: (i) reduce recruitment of weed seedlings from the soil seed bank, (ii) alter crop–weed competitive relations to the benefit of the crop and (iii) ensure gradual reduction of the size of the weed seed bank.

For the farmer, the application of methods based upon ecological concepts will inevitably be a knowledge intensive process. The biggest challenge, will therefore be of how to package and disseminate such knowledge intensive systems in an environment of poor and inefficient extension system that is prevalent in most of the developing countries. This approach also calls for paradigm changes to the way we think and approach weed management. A systematic awareness-raising and capacity-building activities involving all stake holders, including the students, be undertaken to disseminate the concept of ecological weed management for sustainability in agriculture.

Utilization of allelopathy for weed control

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At this meeting, I will focus on three aspects of allelopathy, 1) Screening of allelopathic plants, 2) isolation and identification of allelochemicals in action, and prospective for the future herbicide or plant growth regulator, and 3) Utilization of allelopathic cover plants for practical weed control.

1) As for screening of allelopathic plants, established specific bioassay for allelopathy, named "Plant Box Method", "Sandwich Method" and "Dish-pack Method". By using these methods, about 4,000 plants were examined and made database consisting from 20,000 data. Recently "Rhizosphere soil Method" was established as more practical method to evaluate allelopathy under natural condition on rhizosphere, and found cover crops such as hairy vetch and velvet bean showed potent activity.

2) As for isolation and identification of allelochemicals, new concept based on total activity was developed and named "Total Activity Method". This method is a separation of active chemicals based on total activity, not specific activity, and finally evaluate the contribution of separated chemicals based on the concentration and specific activity of putative chemicals in plants. By using this method, we have isolated many new allelochemicals. One of the recent and most promising allelochemical is *cis*-cinnamic acid and its derivatives. After making more than 400 derivatives, we found that these chemicals have anti-gravitropism activity. Modes of action of identified allelochemicals are evaluated by DNA microarray technique using *Arabidopsis* as receiver plant. Volatile allelochemicals are another target of new type of allelochemicals. Final goal of this study is the utilization of allelochemicals as new agrochemicals for weed control.

3) As for utilization of allelopathic plants, we found that traditional cover crops with allelopathic activity are most useful for the weed control. Some endemic plants in Asia, already known by farmers as cover crops, used in intercropping, hedgerow, or agroforestry, were found to be important as allelopathic plants.

Most promising plants for weed control are hairy vetch and velvet bean. Hairy vetch (*Vicia villosa*) is the most promising plant in Japan and now practically used for weed control in orchard, rice and vegetable production. Now hairy vetch is second important cover crop in Japan, next to traditional Chinese milk vetch. Allelochemical of hairy vetch was identified as cyanamide. Cyanamide was identified as a natural product from hairy vetch first in the world. Although it has been synthesized for over 100 years for industrial and agricultural purposes, but was considered to be absent in natural products.

Velvet bean (*Mucuna pruriens*), native to Indian continent, is promising as weed smothering plants in tropical area. I found an unusual amino acid, L-DOPA is allelochemical by using Total activity method. This legume is a potent alternative food resource. We found a Japanese cultivar, named "Hassjo-mame" is most promising because of its less itching, early-ripening and good weed smothering activity.

Another bean, such as Jack bean and Hyacinth bean are already used in Brazil and Asian countries. Yam bean has been introduced form Meso-America into Southeast Asia about 500 years ago. This leguminous tuber crop is also a very potent allelopathic plant capable for synthetic chemical free production.

For the establishment of sustainable agriculture with proper development in accordance with environmental conservation, combination of allelopathic cover plants used in traditional agriculture might be one of the most important tools in the standpoint of sustainable weed control and healthy vegetable and crop production.

Invasive weeds: A threat to biodiversity and productivity

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An invasive plant also referred to as exotic, introduced, foreign, non-indigenous or non-native, is one that has been introduced by humans intentionally or otherwise or accidentally from one region to another. An alien plant that has escaped from its original ecosystem and is reproducing on its own in the regional flora is considered a naturalized species. Those naturalized aliens that become successful so as to spread in the flora and displace native biota or threaten valued agricultural and environmental resources by the damage it causes are considered invasive. “An Alien species which becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threaten native biological diversity” (IUCN, 2000) as, the consequences can be catastrophic. Introduced species are a greater threat to native biodiversity than pollution, harvest, and disease combined. Foresters, taxonomists and ecologists are now well aware of the problems caused by the invasion of alien species into natural areas. Once established, some alien species have the ability to displace or replace native flora and cause changes in the pattern of plant succession or cropping system. Many invasive plants continue to be admired by people who may not be aware of their weedy nature. Others are recognized as weeds but concerned fail to do their part in preventing their spread. Some species do not even become invasive until they are neglected for a long time. Invasive plants are not all equally invasive. Some only colonize small areas and do not do so aggressively. Others may spread and come to dominate large areas in just a few years. It’s not only India but most of the developed and developing countries are victim of this invasion. Though no valid data is available on the extent of these invasive weeds and estimated loss in India but some information pertaining to *Parthenium hysterophorus* indicates its spread up to 35 million hectares. *Phalaris minor* exists in almost all parts of N. India extending to central and South India and eastern states infesting almost all winter crops drastically affecting the yields of these crops vigorously. In wheat only as per an estimate carried out at DWR the loss due to *Phalaris minor* has been estimated to the tune of Rs. 3,78,000 Crores during 2001-06. Resistance to herbicides is matter of concern where the control of this weed is becoming a great challenge. Some of the invasive weeds like *Parthenium hysterophorus* are highly injurious to human and animal health *Salvinia* etc. pollute the water ways and check the flow of water. Out of estimated 173 species of invasive alien plants in India, *Phalaris minor, Alternanthera philoxeroides, Ageratum* spp.*, Cuscuta* spp, *Ipomea carnea, Mikania micrantha, Cassia uniflora, Chromolaena odorata, Eichhornia crassipes, Lantana camara, Parthenium hysterophorus, Prosopis juliflora, Salvinia molesta, Solanum elaegnifolium* and others are considered highly injurious to crop productivity, biodiversity, human/ animal health and loss of water flow. Recently the weeds which were intercepted in the wheat imports include *Cenchrus tribuloides, Solanum carolinense, Cynoglussum officianale, Ambrosia trifida* and *Viola arvensis*. A project entitled ‘National Invasive Weed Surveillance Programme’ was conceptualized, planned, implemented and monitored by the author during 2008-2011 in 10 states of the country which included W. Bengal, Odisha, Andhra Pradesh, Tamil Nadu, Karnataka, Kerala, Madhya Pradesh, Chhattisgarh, Gujarat and Maharashtra at micro level in all 267 districts of these states. The total budget provisions for 1st phase involved almost 8 Crores to detect the establishment of these weeds. Perhaps, this was the biggest programme on detection of invasive weeds launched globally. For effective monitoring and management of invasive species, knowledge about their ecology, morphology, phenology, reproductive biology, physiology and phyto chemistry is essential. It requires assessing extent and level of infestation in different eco systems; impact on biodiversity and developing management strategies especially through biocontrol. Management of the invasive weeds is expensive, lengthy, and risky because total eradication is required to prevent reestablishment. Effective site-eradication procedures require multi-year treatments, continued monitoring, and follow-up treatments. All infestations on adjacent lands must be treated to prevent reinvasion. Unfortunately, infestations common along railway tracks, roads, and utility right-of-ways are rarely treated for eradication, fostering widespread immigration to adjacent lands. Common methods for control of invasive weed species are: Mechanical, Chemical and Biological control. Biological Control has proven the most effective and environmentally sound approach to their management. Introducing a natural enemy (*e.g.* water hyacinth weevil, *Neochetina* spp. for *Eichhornia; Lantanophaga pussilidactyla* insect for *Lantana camara*, *Zygogramma bicolorata* insect and Cassia *uniflora* plant species for *Parthenium hysterophorus*) for eradication of invasive species is a current focus of interest for biological conservationists. But biological control may not be evenly effective over all areas infested by the invasive species. It is realized that a legal and institutional approach to the country’s biosecurity threat is a prerequisite to long-term success against introduction of invasive species. The government should strengthen its quarantine authority through new legislations which prohibits the introduction of alien species without an approved consent or permit.

Emerging challenges and opportunities for education and research in weed science in India

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Weeds are becoming a major biological constraint to crop production and herbicides are widely used to manage weeds. However, due to concerns over the evolution of herbicide-resistant weeds, shifts toward hard to control weeds, and environmental pollution, the focus of weed science should be on the development of sustainable, ecologically sound, and effective weed control strategies with less reliance on herbicides. For this purpose, there is a need to improve our knowledge of weed biology, genetics, and molecular biology. In my view, research contribution into weed ecology and biology toward sustainable weed management programs is not up to the required standard in India. In the herbicide era, knowledge of weed ecology and biology becomes more important. There is the need to revisit weed research in India in a more holistic manner. Linkages between weed researchers and growers should be mandatory to facilitate the adoption of new and effective technologies. Collaboration of weed researchers with researchers from other disciplines can help in defining and solving the complex weed management challenges. The weed science education system needs to be reoriented and teaching practices need to be improved to prepare graduates for the emerging challenges in weed science.

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Lead lectures

L-1

Impact of climate change on the invasive traits of weeds and sustainable management options

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Invasive weeds degrade ecosystems, and are a threat to plant and animal biodiversity. The literature on biological invasions suggests that only 10% of introduced species become invasive in a new host range. Most introduced plants do not become invasive in the new environment. The invasive behaviour of a weed depends on the weed's genetic variability, biotic factors and climatic factors with which it interacts. The climatic factors that affect the invasive traits of weeds include atmospheric temperature, soil temperature, precipitation, evaporation and CO_2 concentration. The biological traits that are influenced by a change in any one or more of these climatic factors include pattern of assimilate partitioning, induction of dormancy or seed germination, herbivore tolerance, propagule production and distribution, variability of plant architecture and photosynthetic rate. Sustainable options for prevention and management of such invasives include use of traditional and innovative technologies such as use of bio agents such as fishes, suitable avenue plantations, smother crops, plant mulches, inter or alley crops like lotus in rice *etc.* The impact of climate change on invasive traits of weeds and sustainable management options are discussed.

L-2

Identification and mapping of weeds for site specific management using remote sensing techniques

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Weeds are one of the major threats to the natural environment. They are destroying native habitats, threatening native plants and animals and choking our natural systems including rivers, ponds and forests besides reducing farm and forest productivity and in some cases can harm livestock. Remote sensing of weed canopies offers a promising technique for detection and delineation of weeds in croplands especially for precision weed management. The developments in spectral and spatial resolution, improvements in feature detection algorithms has enabled the researchers to map the weeds that are spectrally similar to their surroundings. High spectral resolution (hyperspectral) imagery has potential to identify and map the specific weeds. However, multispectral imagery resolution required to map a weed infestation is dependent on the smallest patch size that must be mapped. Specifically, the pixel size of the imagery should be at least one-fourth the area of the smallest patches that need to be mapped. However, the use of satellite imagery for weed detection at the early stages of weed growth is limited by the lack of spatial and spectral resolution of the satellite sensors to detect small plants. Unmanned aerial vehicles (UAVs) or helicopters sometimes called Drones operated by remote control drones are an alternative means of collecting high spatial and temporal resolution Visible (VIS) and Near Infra-Red (NIR) imagery. The current focus of the research is on developing algorithms for weed detection, mapping and site specific weed management using data mining and Artificial Neural Network (ANN) techniques.

The dormancy breaker plus herbicides: A new approach for weed management

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Soybean-wheat is an important double-cropping system on the Vertisols in central India. This system is further encouraged for sustainable crop production in the North and North-western Indo-Gangetic Plains of India, particularly where rice-wheat cropping system (~10.5 million ha) is dominant. The rice-wheat system has encountered a host of problems related to water, soil, nutrients, weeds, greenhouse gases *etc.* But, multiple flushes of weeds, comprising of grassy, broad-leaved and sedges emerge in soybean during the rainy season due to the differences in dormancy behaviours. The dormancies could be primary, secondary and enforced dormancies in weeds, which lead to periodicity in germination of weeds across crop growth stages, and make weed control a repetitive practice. Usually 3-4 flushes of weeds during the rainy season and 1-2 flushes of weeds during winter occur in the crop fields, which results in crop yield losses. Repeated applications of selective herbicides can lead to weed shift in favour of perennial weeds like *Cyperus rotundus* and may trigger development of resistance in weeds against herbicides. Therefore, this experiment was designed to find out an effective dormancy breaker and selective herbicides mixtures, whose combination can provide better weed control and higher yields and income in soybean and wheat. Identifying a cost-effective dormancy breaker and optimizing its dose in combination with herbicides, particularly imazethapyr with 25% reduced than recommended dose of pendimethalin in soybean were the specific objectives.

Three experiments were undertaken during 2008-2011 in soybean, and during 2010-11 and 2011-12 in wheat at the ICAR-Indian Agricultural Research Institute, New Delhi. Experimental field soil was alluvium (Typic Ustochrepts; order Inceptisol) and sandy-loam. It had organic C 0.51% and pH 7.8. The soil available P (19.1 kg P/ha) and K (190.8 kg K/ha) were medium, but available N (274.6 kg N/ha) was low.

The KNO_3 and GA_3 dormancy breakers tested were found equally effective in breaking dormancy in weeds, but KNO_3 was less costly than GA_3. Their respective higher doses proved more effective than the lower ones. A concentration of KNO_3 (6%) was more effective against weeds than KNO_3 (3%) and provided higher yields of soybean and wheat. Annual weeds control by 99.1% and *Cyperus rotundus* control by 83.3% was achieved due to a treatment of KNO_3 (6%) + pendimethalin 0.75 kg/ha + imazethapyr 0.100 kg/ha. This treatment also gave higher soybean yield and net returns. Among the tank-mixtures tested, a tank-mixture, which involved clodinafop 0.06 kg/ha + metsulfuron 0.006 kg/ha was more effective against weeds and gave almost 3% higher wheat yield than weed-free control.

This new approach would exhaust seed/tuber bank over times, reduce the application cost of herbicides by 50%, and the dose and residue of pendimethalin by 25%. This can be adopted across the states of India under irrigated agro-ecosystems and other tropical countries, having similarity in edaphic and climatic conditions. The recommendation for soybean would be applicable to pigeon pea, green gram and groundnut as well.

L-4

Mechanization in weed management – A global status review

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Weeds are a perennial problem in all crops. These are omnipresent and have affinity with the crop plants and therefore, compete for soil nutrients, moisture and sunlight. Many a times these have a detrimental effect on the crop yield and quality, if not controlled. Several methods are adopted for control of weeds in crops. Needless to say, manual weed removal is the best method, however, this method cannot be adopted except in very small fields. Among the other methods, mechanical and chemical weed control are very popular worldwide. But because of toxic effects of chemicals on the crop plants as well as on the soil, of late, these methods are less popular. Therefore, mechanical methods of different kinds are practiced which vary from small hand tools and self-propelled machines to bigger tractor drawn equipment. To economize on the machine time, cost of weeding and for higher efficiency of the operation several modern technology driven machines equipment including robots are being used.

The researchers in the present paper have made an attempt to inform the readership with a good amount of review and discussion on the important weeding parameters including mechanics of manual weeding. Further information on all the different machines and equipment available worldwide are also presented. However, more details of the units could be searched in the cited references.

L-5

Application of advanced sensing technologies for precision weed detection and management

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Routine scouting for weeds to identify specific species, level of infestation, and site of occurrence is critical for implementation of effective management programs. The recent proliferation of herbicide-resistant weeds in many cropping systems warrant effective scouting and selection of suitable management options. Manual scouting is affected by weather conditions and is subject to variability and human error. Recent advancements in sensing technologies can provide a convenient means for precision weed detection, infestation assessment, and management. Research activities are being conducted in this regard at Texas A&M University, College Station, to utilize unmanned aerial system (UAS) - as well as proximal sensing-technologies to develop some fundamental understanding of the spectral signatures of different weed species. Multispectral, hyperspectral and thermal sensors are currently being utilized by the team in weed management applications. Further, herbicide applications using UAS platforms are also being investigated. The progress made so far provides promise for further research and development of precision weed detection and management technologies in production agriculture.

Aquatic weed management through improved technology interventions in culture based fisheries

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Biotic stresses such as weeds, pests and pathogens account for the loss of significant portion of agricultural produce. Wide ecological amplitudes of weeds give them advantages over other plants to exploit more successfully disturbed habitat and changed environmental conditions. Aquatic weeds are undesirable vegetation that reproduce and their excessive growths can not only have a detrimental effect on water body and its inhabitants, but also provide breeding and harbour predatory insects. On the basis of the growth, aquatic weeds that occur in fish ponds have been categorised in the five groups: floating weeds, emergent weeds, submerged weeds, marginal weeds, and algal weeds. Floating aquatic weeds such as *Pistia, Salvinia, Eichhornia,* duckweeds and submerged weed such as *Hydrilla* are of major concern due to their contribution for vector mosquitos proliferation. Invasive aquatic weed management is the challenging task. Traditional mechanical and manual methods are labour consuming and considering cost, broad-spectrum, persistence and environmental impact of chemical measures, indicates the need of biological methods for weed control. The inland open water bodies of India such as reservoirs, wetlands contribute substantially to fish production and are managed on the basis of most common mode of enhancement *i.e.* culture based fisheries, or the other various forms of enhancement intermediate to culture and capture fishery norms such as stock enhancement, species enhancement, environmental enhancement, management enhancement and enhancement through new culture systems. With nearly 1.48 million ha of around 19134 small reservoirs, 200000 ha of flood plain wetlands, and 40,000 ha of estuarine wetlands, there is a huge potential for developing culture based fisheries in the Country. The current fish yield per year from small reservoirs and wetlands, however, remains much below the estimated production potential. Certain weedivorous fish species can be used as voracious herbivore for bio-controlling weed, as they build nests using weeds and twigs and shows a feeding predilection towards aquatic weeds. The fishes feed mainly submerged plants followed by small floating plants. The fishes, which are considered to be tested for controlling submerged weeds are *Ctenopharyngodon idella*, *Puntius javanicus*, *Pulchellus pulchellus*, *Tilapia mossambica*, *T. melanopleura* and *Ophronemus gorami*. The common carp *Cyprinus carpio* helps in uprooting of certain plants. Pearl spot *Etroplus suratensis* and silver carp *Hypophthalmichthys molitrix* feed on filamentous algae and algal bloom. In the present review paper, the culture based fisheries, where the fish harvest is mainly dependent on artificial stocking, has been highlighted as an ideal strategy for weed control as it can bring perceptible benefits to the community. Integrated multi trophic aquaculture is advantageous in terms of much commercial value both the economic and environmental benefits of growing finfish, shellfish and aquatic plants together. The use of aquatic weeds as feed for fish could be economically and environmentally viable method of controlling the aquatic weeds.

Risk associated with the weed seeds in imported grain

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While examining the seed samples drawn from imported consignment a total of five exotic weed species which are listed in the Plant Quarantine (Regulation of Import into India) Order, 2003 were intercepted and identified up to species level. These are *Bromus secalinus*, *Cuscuta australis*, *Cynoglossum officinale, Centaurea maculosa* and *Cichorium pumilum*. All the weed seeds were found viable even after long storage hence, they could grow and spread in our fields.

Internationally traded grain commodities are recognized as a pathway for the introduction of weed seeds into new areas. Many weed seeds associated with grain crops in the field are harvested along with the crop and can be difficult to remove due to similarities in shape and size of the seeds. Depending on the destination and intended end use of the grain some of these seeds may be introduced into new environments suitable for growth and establishment. Several studies have reported large numbers of contaminant weed species found in sampled grain commodities (Muthaiyan *et al*. 1984 and Singh *et al*. 2000) Our farmers are already struggling to control weeds in their cultivated fields and problem will be further aggravated, if exotic weeds are introduced into our country along with imports of food grains. In view of the above, grain grain consignment imported through Mumbai port from different countries during 2016-17 were screened for presence of weed seeds specially to determine the presence of exotic weed seeds.

Five consignment of niger, coriander, wheat and carrot imported from Ethiopia, Italy, USA and Russian Federation for consumption and propagation, respectively were screened for the presence of weed seeds. Ten samples of one kg each were drawn from each container and a composite sample was made by mixing all the ten samples. From this composite sample, one working sample of one kg was drawn for detailed examination. All working samples of niger, coriander and carrot were examined for weed seeds by passing through sieves of different pore sizes. Then each sample was spread in a thin uniform layer on a clean white drawing sheet and examined with the help of illuminated magnifier and all weed seeds were collected. These weed seeds were segregated into different types on the basis of their shape, size, colour, texture and presence of any attachment.

Weed seeds were identified on the basis of their morphological characters by consulting identification keys and also with the help of Weed Seed Identification Kit. In few cases, weed seeds were subjected to grow-out test in glass house in isolation and were identified on the basis of their vegetative and floral characters of plants.

Five exotic weed species which are listed in the Plant Quarantine (Regulation of Import into India) Order, 2003 were intercepted and identified up to species level. These are *Bromus secalinus*, *Cuscuta australis, Cynoglossum officinale, Centaurea maculosa* and *Cichorium pumilum*. All the weed seeds were found viable even after long storage hence, they could grow and spread in our fields. The consignments were either deported or recommended for destruction to reduce plant quarantine risk and to safeguard our agriculture. On the basis of this study it is concluded that dangerous and potentially dangerous exotic weeds can be introduced into our country with bulk imports of grain. It is necessary to review the plant quarantine regulations to prevent the introduction of exotic weeds into our country in future.

Herbicide-resistant crop technology in the USA 24 years after commercialization: Current status and future outlook

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The era of herbicide-resistant (HR) crop technology began with the commercialization of bromoxynil-resistant cotton and glufosinate-resistant canola in 1995 followed by several crops resistant to glyphosate and glufosinate. HR crops have had a phenomenal impact on weed management over the past twenty-four years since their introduction. HR crops, predominantly glyphosate-resistant (GR) crops have been widely grown in several countries where adopted, since the mid-1990s. GR crops represent a revolutionary breakthrough in weed control technology and was a blessing for growers as it provided simple, flexible, effective, and economical weed management options. Although bromoxynil-resistant canola and cotton (since discontinued) and glufosinate-resistant (canola, corn, cotton, soybean) crops were available, GR crops are the most successful transgenic crops with heavy use of glyphosate and dominated the modern cropping systems. Glyphosate provides effective control of a broad-spectrum of weeds and was often only herbicide used for managing weeds in GR crops. Glyphosate has become a victim of its own success – used too often on same area with no diversity in weed management. Over-reliance on glyphosate and a lack of diversity in weed control tactics have increased selection pressure that led to the evolution of GR weeds and weed shifts toward difficult-to-control weeds. As of July 2018, 42 weed species have developed resistance to glyphosate globally. Evolution of weeds resistant to glyphosate has diminished its utility considerably. Efficacy of glyphosate continues to decline as more weeds develop resistance. The next generation of multiple HR crops that combine glyphosate resistance with resistance to other herbicides has been pursued vigorously by several agrochemical industries. The era of multiple herbicide-resistant crop technology began with the introduction of corn resistant to glyphosate and glufosinate in 2006. It was followed by cotton (glyphosate + glufosinate) in 2014, cotton and soybean (glyphosate + dicamba) in 2017, cotton and soybean (glyphosate + glufosinate + 2, 4-D) in 2018, and corn (glyphosate + 2, 4-D + ACCase) in 2018. These stacked-trait crops will provide new options with existing herbicides but will not be the total weed management solution because several weeds have already evolved resistance to these herbicides. HR crop technology alone cannot provide total weed control and must be integrated with other control methods (cultural, mechanical, chemical, and biological where available) to increase the diversity of weed control tactics. The future weed management tactics look a lot more like the ones used in the past *i.e.*, the pre-HR crop era. GR weeds are not yet a problem in many parts of the world, especially where GR crops are not commercialized, lessons can be learnt to take proactive actions to conserve the sustainability of glyphosate.

Novel mechanisms of herbicide resistance in Weeds: Opportunities for crop improvement

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Evolution of herbicide resistance in weed species is an important constraint to crop production around the globe. However, the development and availability of herbicide-resistant crops are valuable because such technology enables effective weed control and allows for practice of no-till agriculture. Many agriculturally important weed species throughout the world have naturally evolved resistance to several major herbicides used in our agriculture, while innovative and advanced technologies have been used to create herbicide-resistant crops. The investigation of physiological, genetic, and molecular mechanisms of weed resistance to herbicides have uncovered several novel, and exciting results related to fundamental, evolutionary mechanisms of herbicide resistance in weeds, and they have established classic examples of the rapid evolution of adaptive traits in higher organisms, specifically regarding the evolution of resistance to glyphosate, one of the important herbicides used in crop production. With the introduction and wide acceptance of Roundup Ready crops in many countries, glyphosate has been used extensively for weed control, consequently, many weeds have developed resistance to glyphosate. The target site of glyphosate is 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), an important enzyme in the shikimate pathway. Several types of mutations including amplification of *EPSPS* gene can bestow weed resistance to this herbicide. Recently, our molecular cytogenetic research indicated that the *EPSPS* gene amplification in glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*), one of the top problem weeds of the USA, was driven by extra-chromosomal, circular DNA (eccDNA) molecules (Koo *et al.* 2018. PNAS doi/10.1073/pnas.1719354115). Each eccDNA carried one copy of the target gene *EPSPS*. Furthermore, we also found chromosomal aneuploidy including the formation of ring chromosomes (Koo *et al.* 2018; Plant Physiology 176: 1932; see also commentary by Yu Y (2018) Plant Physiology doi/10.1104/pp.18.00083) carrying *EPSPS* copies conferring glyphosate resistance in common waterhemp (*Amaranthus tuberculatus*) another problem weed of Midwestern USA. Although the underlying mechanisms of such response are known, these results are fascinating and support McClintock's proposed concept of genome adaption to stress. These results help us to understand current knowledge gaps in weed biology and physiology and, the evolution of herbicide resistance. Future research uncovering the molecular basis of these novel mechanisms of glyphosate resistance may help use this information for crop improvement which can facilitate the creation of robust herbicide-resistant crops. More importantly, these results also provide valuable information to design prudent weed management strategies.

Current challenges and sustainable weed management into the future: Call for transdisciplinary approach

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Herbicides are a primary tool for weed control in major crop production systems of the world. With the migration of rural populations to urban areas and concomitant decline in agricultural labor force, dependence on herbicides for weed control has increased considerably in production agriculture. Furthermore, the rapid adoption of herbicide-resistant crop technologies has reduced weed control diversity, especially in glyphosate-resistant crops, *viz.*, corn, soybean, and cotton predominant in the North America since mid-1990. This increased reliance on herbicides and the concurrent selection pressure have resulted in a rise in cases of multiple herbicide-resistant weed species, leaving farmers with few or no herbicide options for controlling these weeds in major agronomic crops. As of 2018, 255 weed species have evolved resistance to 163 different herbicides representing 23 of the 26 known herbicide sites of action in 92 crops in 70 countries. In the USA, a total of 17 weed species evolved resistance to glyphosate, mostly in GR cropping systems. With no upcoming new modes of action, the challenge is how to insert sustainable weed management practices while addressing various socioeconomic and regulatory needs that drive farmer decisions to manage herbicide resistance. Sustainable weed management strategies that aim to slow or prevent the evolution of herbicide resistance and preserve existing herbicide resources must be based on an improved understanding of ecological and evolutionary factors that drive selection in weed populations.

Herbicide resistance management decisions should be based on an improved knowledge of weed biology and ecology, with the ultimate goal to prevent weed seed inputs to the soil seed bank. This would require a cropping systems-level approach to manage weed seed banks over multiple growing seasons rather than a single cropping season/year. Considering herbicide susceptibility as a common pool resource shared by growers and pollen and seed mediated gene flow of herbicide resistance, there is a need to aggregate herbicide resistance management strategies at large spatial scales (landscapes) compared to an individual farm level management strategy.

A multi-tactic approach that integrates old and new weed control technologies should be the norm. Non-chemical approaches including cover crops, diversified crop rotations, competitive cultivars, high seeding rates, narrow row spacing, and harvest weed seed control (HWSC) tactics should be integrated into the current and future weed management programs. Transdisciplinary collaborations would be needed to better understand plant-pathogen interactions that can lead to development of novel bio-control agents or bioherbicides. Molecular biology, genomics, and bioinformatics can provide new insights into plant competition, plant pathogen interactions, crop improvement, and gene silencing (iRNA technology). Fundamental mechanisms underlying plant-plant interactions can be used to improve crop competition against weeds (altered crop growth, early canopy development, allelopathy *etc.*). A mechanistic understanding of the weed seed bank decline as a result of plant pathogens and soil-borne herbivores especially in conservation tillage systems will aid in attaining resilient weed control systems. Computer simulation modelling is an essential tool to understand how different management factors interact to affect the evolutionary and population dynamics of herbicide resistance, and thus aid in predicting and managing herbicide resistance. Recent advances in robotics and remote sensing technologies based on machine learning and automation such as hyperspectral imaging to distinguish weed species in crops or early detection of herbicide-resistant weed patches in a crop field will promote precision weed control for a sustainable agriculture.

Importance of allelopathy in agriculture: Bioavailability and functions of allelochemicals in soil environment

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Weed invasion and subsequent infestation represents a major problem in crop production. Chemical weed control is the major management tactic used in conventional agriculture. Complementary strategies to herbicides are increasingly being investigated. The importance of allelopathy has been considered for weed management over the years. However, the relevance of allelopathy has been highly discussed due to the lack of phytotoxic concentrations of allelochemicals under field conditions. To demonstrate allelopathy, one must identify one or more phytotoxins produced by the putative allelopathic plant or identify a compound(s) produced by the donor plant that is converted to a phytotoxin in the soil complex. The compound(s) must be present in sufficient quantity (in time and space) in the soil for allelopathic effects in controlling weeds. Allelochemicals are generally weak phytotoxins. Most of the allelochemicals are present at low concentrations, and undergo rapid chemical and biological degradation in the soil.

Cover crop species like *Brassica nigra, Fagopyrum esculentum, Glycine max, Helianthus annuus, Secale cereale, Sorghum bicolor, Triticum aestivum*, and *Zea may* have been used in weed management on a limited basis. Crop residues from existing crop or rotational crops can provide selective weed control through their physical presence on the soil surface and/or through the release of allelochemicals. Some of the allelochemicals have been reported to play a role in weed management, including phenolic acids, DIBOA, DIBOA-glycoside, and BOA, isothiocyanate, fatty acids, isoflavonoids, juglone, scopoletin, hydroxamic acids, dhurrin, and sorgoleone.

A living and dynamic soil system influences the fate and functions of allelochemicals in time and space. The bioavailability of allelochemicals in the soil is dependent on processes such as adsorption, leaching and degradations by abiotic and biotic factors. The clay types, organic matter, and soil pH can affect the bioavailability of allelochemicals in the soil. Thus, the allelopathic potential of many compounds may not be expressed in some soils because of the chemical adsorption to soil colloids. Examples of such compounds are benzoic acid, catechin, coumaric acid, dihydroxyphenylalanine, ferulic acid, hydroxybenzoic acid, sorgoleone, vanillic acid, and others. The resulting concentrations (sub-toxic) of any of these allelochemicals in soil matrix may have a variety of functions that influence seed germination, seedling emergence, plant growth suppression, nutrient acquisition or soil microbial activity.

Soils may also influence the relative activity of allelochemicals in combination(s). The persistence of allelochemical mixtures may be enhanced in soil environment. In one of our studies, we found that one compound in combination can make the bioavailability and half-life of others greater in soil, because of competitive sorption and preferential degradation. Allelochemicals may also help plants to acquire nutrients in infertile soils which give competitive advantage to the donor plant over its neighbors. Current available research on various aspects of allelochemicals in soil complex will be presented at the conference.

In my view, future allelopathic research should be focused on mechanisms facilitating persistence of allelochemicals in soil environment and characterization of complementary roles of these compounds in plant growth and development. The bioavailability of allelochemicals under field conditions must be established for its effective role in weed management. Currently, we face challenges and opportunities in using allelopathy as a part of weed management strategies in today's production agriculture.

Herbicides in agricultural industry-future prospects & scope

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At present, in India nearly 272 pesticide compounds consisting of Insecticides, Fungicides & Herbicides, 555 formulations of these compounds and 27 combination products of Herbicides are registered with CIB legal in India. Currently India is the largest producer of pesticides in Asia and ranks 12th in world for application of pesticides. The earlier attempt in India to control weeds by herbicides was made in 1937 Punjab for controlling Carthamus oxycantha by using sodium arsenite. 2, 4-D was first tested in India in 1946. Since then a number of herbicides have been imported and tested for their effectiveness in controlling many weed species. At present there is lot of scope for use of herbicide due to shortage of labour and increases in wages of farm labour. New generation is focusing towards biological control of weeds to reduce environmental impact and non target area pollution. Mycoherbicides offer an innovative approach to the management of weeds using formulated fungal phytopathogens or their natural compounds. Key for the development of biological agents such as mycoherbicides and phytotoxins are as effective as their chemical weedicides and are practical components of weed management. Mycoherbicides are practical, reliable, cost-effective for their production, stabilization, formulation, and application. Some of the advantages of Mycoherbicide over traditional chemical herbicides are their specificity for the target weed; absence of adverse effects on humans, wildlife or farm animals, rapid degradation and absence of residues in surface or ground water, crops, soil or food chains.

So the purpose of present paper is to minimize risk of application of chemical herbicides with their regulated and controlled application as well as focuses on the importance of bio-pesticides and Integrated Weed Management for sustainable agriculture. We will also brief highlights about our significant progress in the development and application of mycoherbicide for weed *Parthenium hysterophorus*, *Lantana camara* and *Eichhornia crassipes.*

Weed management in conservation agriculture systems in India: Myths, realities and way forward

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Conservation Agriculture (CA) is an ecosystem approach to regenerative sustainable agriculture and land management based on the practical application of locally-adapted three interlinked principles: (i) continuous no or minimum mechanical soil disturbance (no-till seeding/planting and weeding, and minimum soil disturbance with all other farm operations including harvesting); (ii) permanent maintenance of soil much cover (crop biomass, stubble and cover crops); and (iii) diversification of cropping system (environmentally and socially-adapted rotations and/or sequences and/or associations involving annuals and perennials, including legumes and cover crops), along with other complementary good agricultural production and land management practices. These production systems are considered to be more innovative, knowledge-intensive and resource-use efficient, and help in overcoming the problems associated with conventional agricultural systems.

CA systems have been adopted globally in view of the resource degradation problems and rising production costs. In fact this change was triggered from early 1970s due to the energy crisis and erosion hazards due to repeated tillage leading to loss of top fertile soil. Since then the area under CA has increased gradually and more rapidly in the last decade in different continents of the world. Presently the total area under CA is about 180 M ha largely concentrated in north and south America, Australia and Europe. In Asia and particularly in south-east Asia, the adoption of CA has been rather slow but progressing gradually.

In India CA systems have been adopted partially since early 1990s in some regions in diverse cropping systems. The area under zero-tillage (ZT) wheat after puddle transplanted rice increased in the north-western Indo-Gangetic Plains and reached around 3 M ha during the early years of this century. Similarly, ZT maize or sorghum following rice in coastal Andhra Pradesh and also in some areas of Karnataka; ZT mustard following rice in Manipur and other areas of north-eastern hill region; ZT wheat, mustard and chickpea in the vertisols of central India have made significant progress in the last few years.

An analysis of the research publications over the last 2 decades have revealed that number of articles dealing with CA-based research topics such as zero-tillage and residue management, and their interaction with nutrients, water and weed control have increased progressively over the years. While there were only a few sporadic cases of such references during the 1980s, the CA-based research has received greater attention especially in the last 10 years. It has been noticed that in majority of trials, yield gains (>10%) were reported under CA (ZT with residue) compared with the conventional systems in diverse crops and cropping systems. Only a few papers (<10%) have reported lower yields under ZT than the conventional system due to the problems associated with poor germination and crop growth, soil compaction and weed control.

In the CA system, the weed management strategy involves integrated approach of zero-till seeding, surface cover as mulch, cover cropping, and rational use of herbicides. In fact the focus is more on preventive measures involving full season weed control, and reducing the weed seed bank through killing weed plants before flowering, before sowing of the crop as well as at harvest. The weed seeds under CA are concentrated more at the soil surface which are predated by birds, ants, termites etc. These seeds germinate in 1-2 flushes after sowing and are killed through pre- and post-emergence herbicides. The small proportion of weed seeds lying in the deeper layers (>10 cm) are not able to come up. Further the mulch cover on the soil surface provides restricted light penetration and also a physical hindrance to the germinating seedlings. Some perennial weeds may proliferate which must be nipped in the bud before they propagate and spread on larger area. It has been amply proved through long-term CA studies that adoption of a well planned strategy results in very good weed control and reduces weed infestations over the years unlike in the conventional tillage systems.

Despite the availability of vast amount of literature and positive benefits, the adoption of CA on farmers' fields is lacking in India and not progressing at the same speed as in other parts of the world. This is primarily due to the operational constraints, lack of awareness and will power to change from the existing age-old system. There are still some apprehensions in the minds of researchers and extension workers who are not willing to take the first step of adopting the technology on their research farms. Some of the perceived myths and factual realities are mentioned below:

CA results in soil compaction and formation of hard pan; CA results in low water infiltration in the soil profile, leading to waterlogging; CA competes with crop residues which are fed to animals.; CA increases weed infestations; CA requires herbicides for weed control, which are not environment-friendly; CA increases insect and disease infestations; CA requires more chemical fertilizers; CA causes nutrient immobilization; CA results in soil moisture loss due to evaporation; CA results in poor germination and seedling emergence; Retention of crop residues under CA hinders seedling emergence; CA is not feasible on small-holder farms; CA requires heavy machinery which is too costly and not available in most areas; CA is suitable only for specific soil and climatic conditions; CA will increase crop residue load over time; CA requires breaking of the cycle after some years.; CA results in lower productivity.

CA is a highly specialized technology, requiring optimum conditions and utmost care for its successful adoption. It is essential to follow all the principles of CA in a holistic manner coupled with other modification in cultivation practices. Failure of CA-based farming at some locations may be due to the following seasons:

Lack of assessment of the time period between conversion of native vegetative and no-till adoption; Lack of knowledge or experience on how to manage crops with no-tillage techniques; Lack of a systems approach when eliminating tillage; No-tillage may have been performed with bare soil conditions or with insufficient crop cover with crop residues; Lack of experience of the machine operator at seeding; Inadequate no-tillage machinery, leading to poor plant establishment; Poor control of weeds and other pests; Nitrogen fertilization may not have been adjusted during the first few years of applying no-tillage technology; No-tillage may have been implemented on an extremely degraded and/or eroded soil; Inadequate crop rotation diversity.

Conservation agriculture (CA) is the fastest adopted technology globally, presently occupying >180 million ha and expanding at the rate of 10.5 million ha annually. In India systematic research work on CA started about 2 decades ago and picked up especially after 2005. Despite the availability of vast amount of information and positive results of CA, the adoption has not taken place barring some pockets in different regions of the country. There are several myths about CA even among researchers, while there are proven realities to the contrary. For example, weeds are considered as the major limitation in CA while the fact is that weed control including adoption of preventive measures and focusing on weed seed bank is a much better strategy, which results in decreased weed infestation in successive CA cycles. CA is knowledge intensive, requiring greater precision and timeliness of operations. There is a need to change the mindset, which is the greatest handicap in the adoption of CA in India.

Long-term herbicidal weed management on weed control, yield and soil environment in transplanted lowland rice-rice cropping system

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Weed competition is a major constraint in all the rice production systems. All groups of weed species are endangered the rice crops in term of yield. Hence, weed management at appropriate time in rice-rice cropping system is one of the important components in rice production. Hence, field experiments were carried out with objectives to study the influence of weed management on weed shift, productivity and economics in transplanted rice-rice cropping system, to assess the persistent and residue (soil, grain and straw) of herbicides and to estimate the effect of weed management on microbial population and enzyme activity. The field experiment was carried out with different herbicides combinations on system basis which are in vogue at present, during *Rabi* and *Kharif* (December, 2015 to October, 2017) seasons, at TNAU, Coimbatore and laid out in a randomized block design with four replications.

The relative density of grasses and broad-leaved weeds were dominant in all the treatments at 60 DAT. The relative density of sedges was more in hand weeding twice and weedy check treatments. Among the grasses, *Echinochloa crusgalli* was predominant and *Ludwigia parviflora* was dominant species in broad-leaved weeds. Lower total weed density was recorded in herbicide treatments than hand weeding. Significantly lower total weed density was recorded with PE pyrazosulfuron-ethyl (10% WP) *fb* hand weeding. Hand weeding recorded significantly higher total weed dry weight than chemical treatments. PE pyrazosulfuron-ethyl (10% WP) *fb* hand weeding recorded lesser total weed dry weight at 60 DAT which was comparable with PE bensulfuron-methyl (0.6%) + pretilachlor (6.6%) *fb* hand weeding. Herbicide treatments had significant influence on the number of productive tillers/m^2. Significantly higher number of productive tillers was recorded with PE bensulfuron-methyl (0.6%) + pretilachlor (6.6%) *fb* hand weeding, whereas it was on par with PE pyrasosulfuron ethyl (10% WP) *fb* POE bispyribac sodium (10% EC). Among the different herbicide combination, significantly higher grain yield and income was obtained with PE bensulfuron-methyl (0.6%) + pretilachlor (6.6%) *fb* hand weeding during *Rabi* 2015-16. Among the different herbicide combination, significantly higher grain yield and income was obtained with PE pyrazosulfuron-ethyl (10% WP) *fb* hand weeding during *Kharif* 2016. All the four herbicides, *viz.* PE pyrazosulfuron-ethyl (10% WP), bensulfuron-methyl (0.6%), pretilachlor and POE bispyribac sodium (10% EC) reduced the soil microflora except actino bacteria and soil enzymes upto 5 days after herbicide application, but after 15 days, the mciroflora were increased 10 times when compared with hand weeding during *Rabi*,2015-16 and *Kharif* 2016. The six bacterial isolates which were predominately during *Kharif* 2016 were identified as *Bacillus* sp. and were coming under the different species of *Bacillus subtilis*, *Bacillus cereus*, *Bacillus licheniformis* and *Bacillus-methylotrophicus*. Residues of all the studied herbicides in soil and rice grain at harvest from both *Rabi* 15-16 and *Kharif* 16 were found below the detection limit of 0.01 mg/kg. Soil nutrients status was also unaffected significantly by the herbicidal weed management practices.

History of chemical weed control: The good, the bad, and the ugly

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Weeds have been in existence much before humans took up cultivation/domestication of crops for food, feed, fuel, and fiber 10,000 years ago. Weeds were mostly controlled for thousands of years by mechanical means. The Romans managed weeds with inorganic compounds. The French used $CuSO_4$ to manage charlock (wild mustard) in wheat in 1896. Between 1900 and 1940, sulphuric acid, arsenicals, and $NaClO_3$ were used in Europe and the U.S The 'Chemical Era of Weed Control' started in the 1940s (1940-45) with discovery of 2, 4-D and other herbicides in the US and UK because of WW II chemical warfare research efforts. 2, 4-Dichlorophenoxy acetic acid was the first herbicide to be used selectively. Since then, several herbicides belonging to different chemical classes and possessing diverse modes of action have been synthesized and commercialized around the world.

Herbicides have become the mainstay of row crop production practices in the developed countries, more so, with the advent of no-till and reduced till cropping systems driven by discovery and development of specific and more active herbicides with various modes of action in the 1970s, 1980s, and 1990s. This trend shifted since the mid 1990s with the introduction of glyphosate-resistant (GR) crops in North and South America. Glyphosate, deemed the herbicide of the 20th century, was the only herbicide being applied in GR alfalfa, canola, corn, cotton, soybean, and sugar beet. Thus, diversity of herbicide use on a single field was severely curtailed and the commercial incentive for development of new or old non-glyphosate mode of action herbicides disappeared. Repeated applications of glyphosate on the same field in the same growing season, or over two or more seasons in a GR crop monoculture or rotation of one GR crop with another GR crop contributed to the widespread occurrence of resistance to glyphosate in several weed species. Multiple herbicide resistant crops, primarily with resistance to auxin-type herbicides such as 2, 4-D and dicamba stacked on top of glyphosate, were the next generation of weed management tools that were recently commercialized (mid 2010s). Herbicides come with several attributes that may be characterized as the Good, the Bad, and the Ugly.

The Good is that herbicides have helped tremendously in increasing crop yields and improving quality of produce by controlling weeds, decreasing drudgery of hand weeding, and enhancing aesthetic value of the agricultural and urban landscapes.

The Bad is that, if not properly used, herbicides could be lost forever due to evolution of herbicide resistance in weed populations.

The Ugly is that, if labels and stewardship are not properly adhered to, resulting consequences include off target movement (for example, dicamba drift), crop injury, health risks to applicators and exposed populace, and leaching and runoff that could be detrimental to aquatic flora and fauna as well as water quality.

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Critical crop -weed competition period – Critical factor for annual planning of weed management to increase sustainable crop productivity

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Sustainable agriculture is a successful resource management to satisfy the changing human needs. Additional 5-6 mt food grains/annum is needed to meet the requirement of country's burgeoning population. Eco-safe appropriate weed pest management can increase the production to the tune of additional 10.0% through annual planning of weed pest management (APWPM - two basic concepts are to diminish the weed seed bank prior to crop planting and further to reduce weed competition at CCWCP by using PE weed control measures) as it causes globally 11.5% and nationally 10.9% production loss (DWR, ICAR, Vision 2050). CCWCP has an immense importance for APWPM that takes the edge off the weed pest losses in crops grown in sequence for sustainable crop production in system agriculture. Field experiments were conducted in RBD with four replicates in plot size of 4 x 5 m at the Viswavidyalaya farm for 2003-18 to study the CCWCP status under APWPM with 6 treatments discretely on Cereals- TR Paddy (*Oryza sativa*) cv Lakshmi (CNM 6), DSR paddy cv Shatabdi (IET 4786), Wheat (*Triticum aestivum*) cv Rajlaksmi (HP 1731) and Maize (*Zea mays*) cv Hybrid GX 888; Pulses- Black gram (*Vigna mungo*) cv Sonali (B-1), Green gram (*Vigna radiata*) cv Sarada (WBU 108), Lentil (*Lens esculenta*) cv Maitree (WBL-77) and Chick pea (*Cicer arietinum*) cv BR-78; Oilseeds- Rapeseed (*Brassica campestris*) cv Binoy (B-9), Mustard (*Brassica juncea*) cv Bhagirathi (RW 351), Groundnut (*Arachis hypogea*) cv Phule Pragati (JL- 24), Soybean (*Glycine max*) cv Improved Pelicon, Sesame (*Sesamum indicum*) cv Rama (IS- 5), and Linseed (*Linum ustatistinum*) cv Subhra; Tuber crop Potato (*Solanum tuberosum*) cv Kufri Chandramukhi; Fibre crop Jute (*Chorchorus olitorius*) cv Nabin (JRO 524), Sugar crop Sugarcane (*Saccharum officinarum*) cv CO 7218, Vegetables- Brinjal (*Solanum melongena*) cv Pusa purple and Okra (*Abelmoschus esculentus*) cv Arka anamica; Spices Chilli (*Capsicum annum*) cv Beldanga and Bulb crop Onion (*Allium cepa*) cv Sukhsagar with all recommended practices including balance nutrition vermicompost + Neem cake + NPKS excepting for weed management where the APWPM was followed. To determine the CCWCP upto 50 DAP weeds are removed by hand whenever visible at 10 days interval (weed interference up to 10 DAP; weed interference up to 20 DAP; weed interference up to 30 DAP; weed interference up to 40 DAP; weed interference up to 50 DAP; weedy check) besides a weedy check. The yield data along with important growth and yield attributes were also recorded besides the weed density and biomass at 10, 20, 30, 40, 50 DAP and at harvest. The results indicated that maintaining minimum weed biomass for all crops by managing weeds upto 30 DAP excepting for onion 20 DAP, TR paddy 40 DAP and sugarcane 60 DAP epitomize the CCWCP in gangetic plains of India. Therefore, considering the weed biomass (by reducing the weed seed bank prior to planting and managing weeds during CCWCP-APWPM) and path correlation data, the productivity can be increased by an average of 45.0, 61.5, 36.4, 42.9, 25.6, 28.4, 52.3, 40.4, 42.5, 49.4, 36.8, 35.6, 41.8, 61.5, 30.0, 51.4, 31.8, 35.6, 32.8, 19.5 and 83.20% in TR paddy, DSR paddy, wheat, maize, black gram, green gram, lentil, bengal gram, rapeseed, mustard, groundnut, soybean, sesame, linseed, potato, jute, sugarcane, brinjal, okra, onion and chilli, respectively in comparison to weedy check treatment due to increase of critical growth (dry matter, LAI, CGR) and yield parameters of respective crops grown under these experiments.

Weed Management in Pulses

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Pulses are the second most important group of crops after cereals and remained integral part of Indian agriculture since time immemorial. They are among the ancient food crops with evidence of their cultivation for over 8,000 years. Pulses are valued for their importance in nutritional security, soil amelioration and sustainable crop production. They also play an important role in protecting the environment from the risk associated with present day high input agriculture. India is the major producer and consumer of pulses in the world. Over a dozen pulse crops including chickpea, pigeonpea, urdbean, mungbean, lentil, cowpea, lathyrus, frenchbean, horsegram, field pea, moth bean, *etc*. are grown in one or the other part of the country throughout the year. The total production of pulses (2017-18) in the country is 25.23 million tonnes from an area of 31.11 million hectares with productivity of 811 kg/ha.

The productivity of pulses, however, continues to be low as they are generally grown in rainfed areas under poor management condition and face various kinds of biotic and abiotic stresses. Weeds are the principal biotic constraints to pulses production. It is estimated that out of total annual losses of pulses from various pests, weeds alone account more than 30%. From various study, it can be inferred that 40 to 110% yield improvement can be achieved in pulses with effective weed management. Therefore, effective weed control in pulses is essential to maximize seed yield and quality and to reduce weed competition in following crops. Adequate weed control can be difficult to achieve because pulses have a relatively low growth habit and open canopy early in the growing season. In India, the manual method of weed control is quite popular and effective and mostly practiced in pulse crops. Of late labour has become unavailable and costly due to intensification/diversification of agriculture and urbanization. The alternative for this is the use of herbicides. But, only few herbicides are registered for the use in pulses and that too for pre-emergence or pre-plant application. Therefore, most of the earlier recommendations in pulses are combination of pre-emergence herbicide and manual weeding. Based on the study at Kanpur, some new post-emergence herbicides like imazethapyr, quizalofop-ethyl, propaquizafop, clodinafop-propargyl, *etc.* were found effective to control weeds in pulses. These herbicides were also tested at different parts of the country through All India Coordinated Project and entered to the recommendations in almost all parts of the country. Recent past, research work has started on development of herbicide resistant varieties. Few lines of winter pulses have shown resistant to post-emergence herbicides like metribuzin and imazethapyr. Similarly, some of the pigeonpea lines have shown resistant to glyphosate. Many cultural practices have been also recommended time-to-time in different pulses. Some of the works on allelochemicals were also done especially to control *Cyperus* spp. in pulse crops. Thus, despite of limited availability of herbicides, at present many options are available to manage weeds effectively in pulse crops.

Biological control of *Parthenium:* Ecological and social indicators of success, challenges and way forward

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Systematic efforts in the biological control of invasive weed, *Parthenium hysterophorus* L. were initiated in 1983 in India with the introduction of exotic beetle, *Zygogramma bicolorata* Pallister (Coleoptera: Chrysomelidae). Since then, the area with beetle defoliation is ever-increasing and spectacular weed suppression is evident in many parts of the country through both the natural spread of the beetle and deliberate introduction by farmers. Our findings to assess the post release ecological impact over two decades suggested that the weed population has been managed effectively to the magnitude of 64.3 per cent with increased richness of native vegetation that replaced this weed over these years. Besides, the carrying capacity of pastures in term of biomass of native grasses has also been increased above 57.1 per cent. The most interesting ecological indicator of success by this beetle that emerged from the public opinion was about restoration of *Cassia tora* while nearly 60 % of respondent opined that they were less apprehensive about the spread of this weed in near future. Nevertheless, the suppression level of this weed has varied over space and time often because of asynchrony between weed biology and the emergence of *Z. bicolorata* in the field. In general, the impact of the beetle has been insignificant in pre monsoon cohorts of the weeds that germinated before the diapaused beetle resumes their activity and multiply late in the season. The ability of this beetle to synchronize its period of activity to the availability of its plant host is likely to play a major role in its establishment and effectiveness as a biological control agent. Therefore, research efforts that may aid in improving the efficacy of biological control are to be focused on manipulation of adult diapauses so as to terminate it early in the season before pre-monsoon *Parthenium* starts flowering. Alternatively, augmentative releases of the laboratory bred beetle, during pre monsoon are necessary to boost the beetle population in the natural conditions. Such releases not only resulted in increased defoliation but also led to encouraging vegetative competition that could further suppress the weed density in the coming years. Although classical control still remains immediate option to suppress this aggressive invaders and there is no denying the fact that the introduction of an exotic beetle have profound effects on weed supression, a shift in feeding preferences of native insect herbivores to this weed will likely have equally dramatic consequences on its population in future. There is a pressing need to examine the effects of local herbivores on its community dynamics and ecosystem function. Further, bio-suppression of this weed could be enhanced by exploring the new research areas especially on selection of superior strains in term of low diapauses and tolerance to herbicides which will also be discussed in this paper.

Weed dynamics and its management in spring planted sugarcane

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Sugarcane (*Saccharum officinarum* L.) is most important commercial crop in India. It is cultivated for cane sugar. Sugar juice is used for making white sugar, brown sugar, and jiggery. During the past five decades, the crop has metamorphosed from sugarcane to fiber cane to alcohol cane to energy cane. The longer period (3-5) weeks before germination and wider spacing and slow initial growth coupled with frequent irrigation or rain at early stages, the crop is infested with a variety of weeds causing significant losses in the crop yield. Apart from cane yield, weeds also impair the juice quality and juice yield of the crop. An experiment was conducted during 2017-18 at agricultural research farm, Banaras Hindu University, Varanasi. To study the effect of weed management practices on density, biomass and yield and profit of crop as affected by weed management treatments. The treatments comprised of diuron at 2.4 and 3.2 kg/ha as pre-emergence (PRE) and post-emergence (POST) treatment, paraquat 2.4 kg/ha as early post-emergence (EPOST), 2, 4-D Na salt 2.6 kg/ha as POST and metribuzin 1.5 kg/ha as PRE were compared with three hoeing at 60,90 and 120 days after planting and untreated control in a randomized complete block design. The effect of treatments on weed dynamics was recorded at 60 days after planting and yield and yield attributes were recorded at harvest stage of the crop. Weeds were counted from 0.5 x 0.5 m^2 quadrat randomly placed in plots of each treatment. Destructive sampling was done to obtain dry from same quadrat and dry matter accumulation by weeds was recorded after drying in oven at appropriate temperature. The weed control efficiency of treatments was recorded on the dry weight basis. Sugarcane variety 'CO0238' was cultivated with recommended practice for the region. The major weeds in the crop were *Dactyloctenium aegyptiu*m (L.) Wild, *Parthenium hysterophorus* L., *Trianthema monogyna* L., *Chenopodium album* L. *Solanum nigrum* L. and *Panicum repens* L. Perennial weed *Cyperus rotundus* L. was also emerged after irrigation and rain shower. Post-emergence application of diuron at 3.2 kg/ha during 2-4 leaf stages of weeds was most effective in reducing weed density, dry biomass of weeds and had maximum weed control efficiency. This treatment was comparable with diuron at 2.4 kg/ha when applied at 2-4 leaf stages of weeds. Pre-emergence application of diuron at same rates was significantly less effective than its POST application. The yield attributing characters *viz.* number and weight of milliable cane, cane length, cane diameter and finally cane yield were recorded maximum when diuron at 3.2 kg/ha was applied as POST. Pre-emergence treatments of diuron and metribuzin were statistically similar in yield, but proved superior over 2, 4-D Na salt 2.6 kg/ha as POST which was least effective against weeds with lowest yield among herbicide treatments. Though, all the herbicides were superior to untreated control in managing weeds and yield of the crop. The net returns and benefit per rupees invested (B:C) was the highest in diuron at 3.2 kg/ha applied during 2-4 leaf stages of weeds.

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Status and strategies of weed management in Hill ecosystems of NE Region of India

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The North-Eastern Region of India, comprising the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura, lies between 21.5° N to 29.5° N latitude and 85.5° E to 97.5° E longitude. The total cropped area of the region is 5.3 million hectares and a population of around 39 million. The region falls under high rainfall zone and the climate ranges from subtropical to alpine. By and large, the region is characterized by fragility, inaccessibility and marginality. Floods, erosion, landslides *etc*. are common to the region due to its peculiar topography, geo-physical settings accentuated by faulty land use systems. The farmers of the region are mostly small and marginal with small land holdings and low investment capacity. Agriculture is the main stay of the people of the NEH region. The agricultural production system in the region is mostly rainfed and monocropping is the predominant system. Slash and burn agriculture (*Jhum*) is still practised (~ 0.88 m ha) in almost all the states except Sikkim on steep slopes with reduced cycle of 2-3 years as against 10-15 years in the past. The shift in the climatic scenario, low availability of resources and mitigation strategies with the farmers make the challenges in North Eastern agriculture further complex. Since 80% of the crop area is under rainfed agriculture, future climate change and variability will potentially impact agriculture production pattern in NER . The temperature is projected to rise by another 3–5 °C in the North Eastern Region of India during the latter third of this century (Cline 2007). Results of the recent study conducted by Ravindranath *et al.* (2011) indicate that majority of the districts in North East India are subject to climate induced vulnerability presently and in the near future. The study conducted by Saikia *et al*. (2012) further substantiate the average reduction in total rainfall, number of rainy days as well as occurrence of dry spells and one day extreme rainfall events in the region. The region is also characterized by difficult terrain, wide variation in slopes, altitudes, land tenure systems and diverse cultivation practices. The productivity of most of the crops in the region is low compared to national average due to a number of constraints. The region is bestowed with high average annual rainfall (2000 mm), favourable temperature, and high humidity almost throughout the year.

Weed infestation is a serious limitation to agricultural productivity. High temperature, adequate soil moisture, high humidity, lack of adoption of appropriate weed management practices *etc*. encourage heavy weed growth with diverse species composition ultimately affecting crop productivity. Loss in crop productivity to the tune of 20-80 % in different crops has been reported by many workers depending upon the season, crop, weed species composition, crop duration, duration of competition, level of weed management practices adopted *etc*. It is also expected that climate variability as witnessed in the region in the form of increased frequency of extreme rainfall events, intermittent drought, flood, significant variation in temperature, *etc.* the weed problem may further aggravate. Manual weeding with small tools and implements is the major way of weeding in hill slopes. Under terrace land situation, use of dry land weeder, grubber, garden hoe, rake *etc*. also gaining popularity. Due to topographical situation as well as cultivation at high altitude, use of herbicides, is yet to become popular in the region. Weed management through manual methods is highly backbreaking, tedious, time consuming as well as labour intensive. An inclusive and integrated way of weed management involving a host of methods like cultural, manual, mechanical *etc*. may be an appropriate strategy for management of weed in hill ecosystems. Intercropping, cover cropping, mixed cropping along with appropriate tillage and residue management, bio-mulching, timely sowing/planting of crops, adoption of appropriate crop rotation, encouraging weed suppressing crop varieties *etc*. may help in over all weed management strategies in hill ecosystems. The annual weed biomass production in the different ecosystems (cropped, non -cropped, forest ecosystems *etc*.) is varied from 5- 20 t/ha (Rajkhowa and Manoj-kumar 2013). Such huge biomass can be easily converted in to quality organic manure (Mahanta *et al*. 2014), and may be a component of overall weed management strategy.

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Toxicological significance of MRLs with special reference to glyphosate: let's talk about

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Weeds compete with crops in various ways for nutrients, sunshine, and moisture. These situations make it necessary to rely on herbicides for effective and timely weed control measures. The use of herbicides as a tool for controlling weeds is very popular mainly due to their high efficiency in controlling diverse weed flora, cost-effectiveness, and their requirement for less labor. Glyphosate (N-phosphonomethyl-glycine) is used expansively as a non-selective herbicide and its use is going to increase further due to the introduction of genetically modified herbicide resistant crops. After absorption to the plants, glyphosate binds and blocks the activity of the enzyme enolpyruvylshikimate-3-phosphate synthase (EPSPS). In the commercial formulation, glyphosate is generally ranging from concentrates containing 41% or more (71%) glyphosate to 1% glyphosate formulations marketed for agricultural use. It is claimed that glyphosate is rapidly inactivated in the soil through adsorption. This enhances the risk of high persistent in soils and sediments, especially in colder agro-ecological climates and in these areas its residues have been found in the soil for up to 3 years. It also inhibits the formation of nitrogen-fixing nodules on clover for up to 4 months after treatment. In March 2015, the International Agency for Research on Cancer (IARC) working group of experts classified glyphosate in Group 2A (*probable human carcinogens*) with strong evidence for a genotoxic mechanism of carcinogenicity. Several independent researchers demonstrated glyphosate negative impacts. These include damage to kidney, liver, and skin cells, as well as disruption to soil and aquatic life. The mode of action of glyphosate is complicated. Not only is glyphosate used as different salts but commercial formulations of it contain surfactants, which vary in nature and concentration. As a result, human poisoning with this herbicide is not with the active ingredient alone but with complex and variable mixtures.

Glyphosate is an essential and important component of conservation agriculture and herbicide (glyphosate) resistance crops (HRC) in which chemical control of weeds is being done by this non-selective herbicide. This results in the wide application of this herbicide in most conservation experiments as well as non-crop fields and enhancing exposure to agricultural fields and risk of residues in agricultural commodities being cultivated by this technique.

Alike other pesticides, maximum residue limits (MRL) of glyphosate is also fixed by national and international bodies. MRL is the maximum concentration of a pesticide residue (expressed as mg/kg), recommended by the Codex Alimentarius Commission or similar authority to be legally permitted in or on food commodities and animal feeds. MRLs are based on good agricultural practices data and foods derived from commodities that comply with the respective MRLs are intended to be toxicologically acceptable. According to CODEX Alimentarius food standards, MRL of glyphosate in various commodities such as cereals (30 mg/kg), soybean (20 mg/kg), sugarcane (2 mg/kg), lentil dry (5 mg/kg), sweet corn (3 mg/kg), peas dry (5 mg/kg), meat/ milk (0.05 mg/kg) , sugarbeet (15 mg/kg) etc has been fixed. However, its acceptable daily intake is adapted to be 0-1 mg/kg bw (WHO, 2016). Wide application of glyphosate enhances the risk of exposure to the consumers eating agricultural commodities containing residues of this herbicide at varying levels.

Effect of nanoparticles on the absorption and translocation of glyphosate in purple nutsedge and its management

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Purple nutsedge *(Cyperus rotundus* L.), considered as one of the most invasive perennial sedge weeds, propagate mainly through a complex underground system of rhizomes, basal bulbs and tubers. Due to dormancy, the tubers remain viable in the soil for quite a longer period and interfere with the crops raised in the subsequent seasons. Most of the foliar applied systemic or non-systemic herbicides did not reach the underground chain of tubers effectively due to their poor translocation leaving the propagules unaffected. Under this situation, a new strategy has to be designed to increase the translocation by breaking the barrier for absorption of foliar applied herbicides by which the tubers dormancy can be broken down and kill the sprouting tubers. Amidst many approaches the newly emerging nano technological approach is expected to results in improved translocation of herbicides and thus manage the weeds in a better way.

Experiment was conducted at the Department of Nanoscience and Technology, Tamil Nadu Agricultural University, Coimbatore to improve the absorption and translocation of glyphosate in *C. rotundus*, by applying the herbicide in sequence with nanoparticles. The *C. rotundus* tubers were planted in pots. Various zero valent metal nanoparticles such as iron oxide, silver, titanium dioxide and zinc oxide nanoparticles were synthesized in lab and applied at the rate of 0.1, 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 g/Lon *C. rotundus* at 10 days after planting. The herbicide glyphosate was prepared at the concentration 50, 100, 200, 300, 400, 500 and 600 ppm using stock solution and sprayed at 11 days after planting (one day after nanoparticles application) with 1% ammonium sulphate and tween 20 solution.

C. rotundus tubers were analyzed for the presence of translocated herbicide in the primary and secondary tubers. It was observed that the highest quantity of glyphosate (40.15 ppm) in the primary tubers with the sequential application of titanium dioxide nanoparticles at 3.0 g followed by glyphosate at 600 ppm. Application of iron oxide nanoparticles at 3.0 g *fb* glyphosate at 600 ppm recorded 26.64 ppm of translocated glyphosate. Silver and zinc oxide nanoparticles (3.0 g) *fb* glyphosate (600 ppm) recorded 21.64 and 21.41 ppm of glyphosate, respectively. Translocation of glyphosate to the secondary tubers of *C. rotundus* was also detected in the sequential application. The lower doses such as glyphosate at 10, 15, 50, 100 and 200 ppm, didn't show any traces of glyphosate in the secondary tubers. Application of glyphosate at 600, 500, 400 and 300 ppm recorded 0.42, 0.21, 0.19 and 0.14 ppm, respectively. Higher translocation of glyphosate (13.04 ppm) to the secondary tubers was observed with the silver nanoparticles at 3.0 g *fb* glyphosate at 600 ppm. Followed by zinc oxide nanoparticles at 3.0 g *fb* glyphosate application at 600 ppm recorded 4.78 ppm. Application of titanium dioxide or iron oxide nanoparticles at 3.0 g *fb* glyphosate at 600 ppm recorded 4.18 and 3.47 ppm of glyphosate, respectively. Effective translocation of glyphosate to both primary and secondary tubers with the sequential application of iron oxide and silver nanoparticles (3.0 g) followed by glyphosate (600 ppm) deterred the sprouting of buds and results in good control of *C. rotundus* compared to titanium dioxide and zinc oxide nanoparticles.

Oral presentations

A taxonomic assessment of asteracean weed acmella in India

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Is one of the common Asteracean herbaceous weeds mostly in the high rainfall areas of the country. The genus is closely allied to another Asteracean genus *Spilanthes,* the genus under the subfamily Verbesininae, wheare as *Acmella* belonged to the subfamily Heliantheae. A study on the diversity of *Acmella* was undertaken to distinguish the taxa under this genus which occur in crop fields as common weeds but have often been referred as *Spilanthes calva* and *S. paniculata,* as Taxonomic identity to the lowest possible rank of the weeds often proved as the key criteria in their successful management.

The distinguishing features of *Acmella* included petiolate leaves, orange yellow to yellow (rarely white) flowers in radiate and discoid capitula and dimorphic fruits (outer trigonous and inner laterally compressed achenes) with pappus of soft bristles or lacking, comparing to sessile leaves, white to purplish white flowers in only discoid capitula and monomorphic fruits (laterally compressed achenes) with pappus of stiff awns in *Spilanthes*.

Among the taxa recognized during the study included *Acmella calva, A. ciliata, A. paniculata* and *A. uliginosa* known from almost all the rice growing states, *A. radicans* var. *radicans* from Tripura, West Bengal and Kerala, *A. radicans* var. *debilis* from Karnataka and Assam, *A. oppositifolia* var. *repens* from Andhra Pradesh and Middle Andamans, out of the cultivated ornamental and medicinal species *A. oeracea* (mostly in Punjab, Delhi and NE India).

Sheela's new species *Spilanthes ghosinis* (published in 2007), and *Spilanthes vazhachalensis* (published in 2010) and one more new species *Spilanthes tetraloba* published by Reshmi and Rajalakshmi in 2014 actually belong to *Acmella* as per the accepted distinguishing features of both the genera.

Present study confirmed the occurrence of the following two taxa in India in abundance as marshland weed as a new taxonomic record for the country:

Acmella brachyglossa Cassini from Assam and Kerala. Reshmi and Rajalakshmi (2016) reported the taxon as a new variety of *Acmella uliginosa* and nomenclatured as var. *pentamera* and reported from Bhudhanur and Panavila of Kerala. In Assam, its occurrence is found to be restricted in some rural areas of Upper Brahmaputra Valley zone as cropland weed in marshy upland situations.

Acmella opposite folia (Lamarck) R.K. Jansen var. ***oppositi folia***: its identity has been confirmed by following Jansen (1985) as the taxon characterized by the presence of coarsely serrated leaves and ciliate achenes with a poorly developed pappus. This taxon is also a common weed in the summer crop fields and their neighbouring marshland situations in the Brahmaputra valley and foothill areas of Assam.

A study on the taxa which have often been confused with *Spilanthes calva* and *S. paniculata* resulted in altogether thirteen taxa belonging to eleven species including one cultivated species. Out of these, two taxa namely *Acmella brachyglossa* and *Acmella oppositifolia* var. *oppositifolia* have never been known from this country and cited here as new record for India.

Authors are thankful to the ICAR, Directorate of Weed Research, and Assam Agricultural University for providing financial assistance and facilities to carry on the study.

Effect of shading on growth, development and reproductive biology of some major weed species of winter season

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Despite the advancement in weed management methods, weeds continue to dominate over crops due to their aggressive competitiveness. Hence, understanding the nature of underpinning crop-weed competition is central to develop weed management methods and their continuous improvements. Competition for light or photosynthetically active radiation (PAR) is the only major above ground competition between the weeds and crops. The competition becomes more important when moisture and nutrients are adequate. Competition for light in plants is unique in a way that the superior competitor both reduces the quantity and changes the quality of light that is available to the less competitive plant. Shading affects the ability of weeds and crops to compete for water and nutrients by reducing the photosynthates available to support root growth. The shading effect of crops can be used as a component in an Integrated Weed Management (IWM) system. Reduction in light, both quality as well as quantity affects morpho-physiology, biomass production and reproductive biology of weeds. Since, both crops and weeds compete for light by shading each other, an understanding of the different competitive potentials of crops and weeds under shade is critical to design suitable IWM strategies.

The present experiment was conducted in winter season 2017 to evaluate the effects of shading on growth, development and reproductive biology of seven major weed species of winter season *viz*. *Phalaris minor, Polypogon monspeliensis*, *Melilotus indica, Medicago denticulata, Lathyrus aphaca, Vicia sativa* and *Solanum nigrum*. The treatments included full sunlight, 55% shade and 75% shade. Data on phenology, biomass partitioning and reproductive biology was recorded for all the species. The total duration was delayed by more than two weeks under 55% shading while under 75% shading, it was delayed by as much as four weeks due to cumulative increases in vegetative and reproductive stages as well as time taken from flowering to maturity. Plant height increased significantly under both the levels of shading. Total aboveground dry matter accumulation decreased by more than 80% under shading and almost two-three fold proportion of dry matter was partitioned towards leaves. Concomitant variation in SLA, RGR, NAR and LAR indicated adaption to shade at whole plant level. The lowest decrease in maximum NAR and RGR was observed in *Polypogon* and *Solanum*, expressing their high competitive ability over other weeds under study. Number of seeds per plant was reduced by 67% under shading as a consequence of proportional reduction in number of fruits/inflorescences. However the number of seeds per fruit remained fairly constant. Chlorophyll a/b ratio was also reduced under shading.

Determining economic threshold of *Phalaris minor* in wheat across nitrogen levels using regression model

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Among the various weeds infesting the wheat crop, *Phalaris minor* Retz. (littleseed canarygrass) is the single most dominant grassy weed in North-western Indo-Gangetic Plains (IGP) of India. Increased nutrient application, particularly N application is known to increase the ability of cereals to suppress the weeds. But the crop-competitiveness depends upon several factors like, time, amount and methods of N application, density of weeds as well as initial population of wheat crop. The economic threshold (ET)-based weed management may lead to rationalization of herbicide use, reducing herbicide intake from the present levels by tailoring doses to the specific weed problems but hardly studies considering *Phalaris minor* densities and nitrogen (N)-doses in combination. Therefore, this study was planned and conducted to evaluate the impact of interference of PM densities on wheat yield across N levels and to determine the ET level of PM in wheat.

The experiment was conducted at the ICAR-Indian Agricultural Research Institute (ICAR-IARI), New Delhi (28°352 N latitude, 77°122 E longitude and at an altitude of 228.6 m above mean sea level) during 2014–15 and 2015–16. The treatments were comprised of three N levels (*i.e.*, 100, 150 and 180 kg N/ha) in main plot, and five infestation levels/ densities of PM (*i.e.*, 0, 10, 20, 40 and 80 PM/m^2) in sub-plots, which were laid out in a split plot design with three replications. A rectangular non-linear hyperbolic regression model was used to determine the ET of PM in wheat across nitrogen levels.

Phalaris minor (PM) tillers and dry weight were significantly decreased as the rate of N increased from 100 to 180 kg/ha across the years and PM densities. A reduction of 25% and 43% in PM tillers was observed as the N doses increased to 150 and 180 kg N/ha, respectively from 100 kg N/ha. Significantly higher grain yield of wheat (5.92 t/ha) was recorded at N_{180} as compared to N_{150} (5.19 t/ha) and N_{100} (3.93 t/ha) across years and PM densities. Application of N_{180} recorded 33.6 and 12.3% higher grain yield over N_{100} and N_{150}, respectively. Among PM densities the highest grain yield was recorded at 0 PM (WFC) over other PM densities. As the density of PM increased from 0 PM to 80 PM, the yield decreased from 5.58 to 4.21 t/ha (~25%). As the N-doses increased, the ET of PM also increases. The ET of PM at N_{100}, N_{150} and N_{180} were ~6, 8 and 9 plants/m^2, respectively, during 2014-15, whereas, during 2015-16 the corresponding ET were ~6, 8 and 11 plants/m^2. The present study has taken several factors into account for the estimation of ET, thus makes PM control decision and fitting models highly economical. These novel results hold great promise in designing weed management strategies for other cropping systems as well, where single weed species is dominant.

Abiotic stress tolerant plant growth promoting rhizobacteria from semi-arid tropical grassy weeds

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The modern and intensive agriculture necessitates immense dependence on fertilizers and pesticides, which cause soil pollution, environmental hazards and residual toxicity in the produce. In many areas, health and productivity of soil reduced to the extent that they cannot sustain profitable farming any more. To avoid these problems, emphasis is now focused on use of bioinoculants in crop production. Rhizobacteria that exerts beneficial effect on plant growth and development are referred to as plant growth promoting rhizobacteria (PGPR). Their application is often associated with increased rate of plant growth, yield and quality. There is now increasing evidence that the use of beneficial rhizosphere microbes can enhance plant's resistance to adverse environmental stresses, *e.g.* drought, salts, nutrient deficiency and heavy metal contaminations. The present investigation is aimed to characterize the unexplored culturable plant growth promoting rhizobacteria diversity of selected weedy grass species and their abiotic stress tolerance levels.

Based on their dominance in each physiographical region of the country, a total of 10 different grass species (*Cenchrus glaucus, Brachiaria reptans*, *Panicum repens*, *Saccharum spontaneum, Cyperus rotundus*, *Chloris barbata, Dactyloctenium aegyptium, Oryza rufipogon, Cynodon dactylon* and *Setaria verticillata*) rhizosphere soils were sampled and the analysis were conducted during 2013-2014. Plant growth promoting rhizobacteria (PGPR) were enumerated and isolated using serial dilution technique. PGPR isolates identified by 16S rRNA gene sequencing. Plant growth promoting traits revealed that the amount of IAA and GA production, P-solubilization, siderophore and HCN production were higher in *Serratia marcescens* (CD1) among the isolates.

Tolerance level to various abiotic stresses such as salt, temperature, desiccation and heavy metals were assessed and the results revealed that these rhizosphere isolates *viz*., *Bacillus* sp. (CG5), *Stenotrophomonas* sp. (SS4) and *Bacillus* sp. (CD2) registered their remarkable ability to tolerate salt upto 7.5%.

Among all, 32 % of the isolates were found to survive at 55ºC. The PGPR isolates *Bacillus* sp. (CG5), *Bacillus* sp. (CBE9) and *Enterobacter sacchari* (SVE9) showed maximum resistance to heavy metals such as Cd^{2+}, Hg^{2+}, Co^{2+}, Ni^{2+} and Zn^{2+}.

The present investigation, unravel the diversity richness of diazotrophic bacteria colonizing in the rhizosphere of naturally growing weedy grass species in different parts of India. Thus, the present work suggested the exploration of these elite PGPR strains having multiple plant growth promoting traits, as bioinoculants for nutrient management and for biotic and abiotic stress mitigation and sustainable crop production with fewer chemical inputs.

Long-term effect of diversified cropping systems and nutrient management practices on weed seed bank dynamics

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Weed seed bank is the store of viable weed seed present on the soil surface and scattered all through the soil profile. Alteration in the crop management practices changes the seed bank characteristics. Understanding the impact of crop rotation and nutrient management on weed seed bank will give supportive data to enhance understanding and improve decision making in weed management. The objective of the present study was to assess the dominant weed flora in the seed bank under diversified cropping systems and nutrient management practices after 13 years.

The seed bank study was conducted from two long-term experiments (rice-based in lowland and maize-based in upland) initiated in the year 2003 at the ICAR-Indian Institute of Pulses Research, Kanpur. Cropping systems comprised of four rice-based systems, *viz*. rice-wheat (RW), rice-chickpea (RC), rice-wheat-mungbean (RWMb), and rice-wheat-rice-chickpea (two years rotation: RWRC) and four upland systems *viz.* maize-wheat (MW), maize-wheat-mungbean (MWMb), maize-wheat-maize-chickpea (two years rotation: MWMC), and pigeonpea-wheat (PW). In both cases, three nutrient management practices, *viz.* control (CT), integrated nutrient management (INM), and recommended inorganic fertilizers (RDF) were undertaken. The experiment was carried out in split-plot design with three replications having cropping system in main plot and nutrient management in subplot. Soil sampling was performed in March, 2016 after harvesting of winter crops in each crop cycle. Samples from 0-7.5 cm and 7.5-15 cm soil depths were collected, bulked, and air-dried in net house. Samples from each treatment were placed in 38 x 25 x 10 plastic trays under natural light. Each plastic tray was filled with 5.5 kg soil. Weed seedlings that emerged were identified, counted and removed. They were converted to no. of seeds germinated/m^2.

The dominant weed flora in seed bank were *Cyperus rotundus*, *Digitaria sanguinalis*, *Leptochloa chinensis, Dactyloctenium aegyptium, Echinochloa colona, Cynodon dactylon* among narrow-leaved and *Trianthema portulacastrum, Eclipta alba, Alternanthera sessilis, Phyllanthus niruri, Convolvulus arvensis, Mollugo pentaphylla, Coronopus didymus, Lathyrus aphaca, Vicia sativa, Medicago denticulata* among broad-leaved weeds. Particularly, *L. chinensis* was the most dominating in lowland condition and *P. niruri* was dominant in upland condition. Weed emergence study revealed that seed bank density was higher at 0-7.5 cm depth than that of 7.5-15 cm depth. In lowland condition, cropping system followed the order of RC > RWMb > RWRC > RW ($P<0.05$) for seedbank density at 0-7.5 cm depth. While, RW system recorded the higher seed density at 7.5-15 cm depth. The INM led to higher weed emergence at 0-7.5 cm depth over RDF. In upland condition, PW system recorded significantly higher weed emergence at both soil depths over other cropping systems. Among nutrient management, CT and INM practices did not differ for weed seed bank density at 0-7.5 cm, however, they were significantly higher over RDF.

It is evident that weed seedling emergence pattern is affected by crop management practices including crop rotation and nutrient management. The weeds like *C. rotundus*, *P. niruri, L. chinensis* and *C. didymus* were pre-dominant in these ecologies. The pulse-inclusive cropping systems can suppress the field weed emergence, hence, maintained higher seed bank density.

Phytoremediation studies with aquatic weeds in artificial wetland

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Among the most important sources of river water pollution in urban and peri-urban environments are sewage from cities, drainage water from different industries, and waste water from dairies. It is estimated that more than 38,000 million litres of sewage water per day is generated, out of which only 35% is treated in India (CPCB 2009). Receiving waste water in surface water bodies results in eutrophication causing deterioration of water quality and affect non-target organisms. Continuous use of such water during winter for irrigation to rabi crops including vegetables accumulate heavy metals such as cadmium, nickel, lead in surface layers of soil and are easily absorbed by vegetables crops which affect human and animal health after its consumption. To cope up with this concern, performance of aquatic weeds, *Eichhornia crassipes* (Mart.) Solms, *Pistia stratiotes* and *Typha latifolia* L. were tested during winter months of 2015 and 2016 respectively. The treatment system comprises of the collection tank, settling tank followed by treatments zone having 3 tanks each of 1200 litre capacity. The water samples were collected from inlet and outlet zone of each tank. The various water parameters were analyzed by multi-parameter water analyzer model Photolab RS12A (WTW make) and heavy metals by AAS (Thermo SOLAR S4). Results indicated that during 2nd run of the pilot scale system, except slight change in electrical conductivity, no change in pH, temperature and total hardness was recorded in water treated with *Pistia stratiotes* and *Eichhornia crassipes*. However, as compared with the turbidity of drain water (64.2 Ntu), lower turbidty of 20.4 and 6.9 Ntu was recorded in water treated with *Pistia* and *Eichhornia*, respectively. Other parameters *viz*. total dissolved salts (TDS), sodium, sulphate, chloride and chromium in water were reduced to the extent of 24.1, 33.1, 68.7, 43.0 and 76.3 % after 5 days treatment with *Eichhornia* respectively. *Typha latifolia* reduced Cr, Ni and Pb to the extent of 91.54, 79.52 and 46.18 % respectively. Besides heavy metals, it also reduced 91.22 and 21.06 per cent of turbidity and EC respectively. *Thus, E. crassipes* and *Typha latifolia* are promising phyto-remediating agents for development of plant consortia for control of point source of pollution in peri-urban areas of Central India.

Identification of wheat cultivar with better competitive ability against weeds in subtropical India

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Weeds – the insidious tyrants on earth has become a major challenge for sustainable crop production. Their infestation sometimes becomes so noxious that famers resort to the abandoning of crop fields. The very existence of the kind of weed flora in the cultivated field depends upon the prevailing soil and climatic characteristics along with different tillage and crop management practices. Yield losses in the cultivation of wheat ranged from 20 to 40%. And to control heavy weed menace, the use of herbicides is considered to be the fastest and assured solution without looking into repercussions arising from the continuous use of poisonous chemicals. Herbicide use alleviates the problem of weed infestation but, non-judicious use may bring environmental problems due to chemical pollution. Reduced dependence on herbicides may reduce the costs of crop production and retard the development of herbicide resistance in weeds. Development and evaluation of competitive wheat cultivars may provide a safe and environmentally benign tool for integrated weed management.

The present study was undertaken on a loamy sand soil to assess the relative competitive ability of four common wheat cultivars namely WH 1105, HD 2967, PBW 621 and HD 3086 against weeds under two weed regimes of weed free and weedy. The experiment was laid out in split plot design with three replications at PAU Ludhiana during 2nd fortnight of November of year 2014-15. The dominant weed species which emerge after sowing were *Malwa neglecta, Phalaris minor, Chenopodium album* and *Rumex* species. Hand weeding was carried out for the weed-free treatments. N, P_2O_5 and K_2O was applied at 120, 62.5 and 30 kg/ha respectively for raising wheat crop. All other cultural operations and plant protection measures were followed as per recommended package of practices to raise a healthy wheat crop. The results revealed that the productive tillers recorded at maturity were significantly low in all the varieties under weedy regime than that obtained under weed free. The productive tillers of HD 3086 were numerically highest but were statistically at par to other varieties. The weed free regime produced 59.6 grains per ear as against 52.1 under weedy regime. The thousand grain weight too followed similar trend. HD 3086 was a week earlier in heading and 4 days early in maturity. Presence of weed flora caused significant lodging of wheat than the weed free crop. The weed free crop significantly produced 10.5 q/ha of extra yield than the weedy crop. Among the varieties, WH 1105 and HD 3086 produced almost similar yields but the differences among the varieties were not significant. The competitive ability was measured by calculating the relative yield loss of different varieties under weedy regime. HD 3086 exhibited better competitive ability by recording only 11.5% of relative yield loss as against 20.3 to 23.6% yield loss in other three varieties.

Effect of organic manures and weed management practices on weeds, yield and soil microbial properties in fennel

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Mulches are commonly used in cultivations of vegetables, spices and medicinal crops and are acceptable in organic farming as well as in crop production that requires reduced use of herbicides to manage weeds. Applying mulches after planting crop or before weeds start to germinate, certainly bring about many benefits to cultivated crops. Negligence towards weed management is one of the most important factor responsible for low productivity. Initial slow growth of seed spices leads to favour severe weed crop competition and reduces growth and yield as high as 91.4 per cent. The present study was carried out to know the combine effect of weed management practices and organic manures on weeds and yield of fennel. A field experiment was conducted at farm of AICRP-Weed Management, Anand Agricultural University, Anand during the *Kharif-Rabi* seasons of 2017-18. The soil of the experimental field was sandy loam in texture with pH of 8.0. The organic carbon, available nitrogen, phosphorus and potash of the soil ranged to 0.36%, 250.4, 34.37 and 146 kg/ha, respectively. The experiment was laid out in a split plot design and replicated thrice. Organic manure: Farm yard manure 20 t/ha and Vermicompost 8.0 t/ha allotted to main plot and weed management strategies: Paddy straw mulch 5 t/ha *fb* HW at 30, 60 days after transplanting (DATP), Paddy straw mulch 10 t/ha *fb* HW at 30, 60 DATP, Intercultring(IC) + HW at 30 and 60 DATP *fb* earthing-up at 75 DATP, pendimethalin 0.75 kg/ha pre-transplant *fb* IC + HW at 40 DATP and weedy check were relegated to sub plot. The fennel cv. '*GF 12*' was transplanted in the experimental field on 15 September 2017 keeping the row to row distance of 90 cm and plant to plant distance of 60 cm. Standard packages of practices were followed throughout the growing season. Organic manures were applied as per treatment directly in the furrow as well as pendimethalin was also applied pre transplanting with the help of a knapsack sprayer fitted with flat fan nozzle with a spray volume of 600 L/ha. Paddy straw mulch was spread after transplanting as per the treatment. Manual weeding operation like interculturing and hand weeding carried out as per the treatments. The results revealed that application of paddy straw mulch at 5 t/ha and 10 t/ha *fb* HW at 30 and 60 days after transplanting (DATP)and IC + HW at 30 and 60 DATP *fb* earthing-up at 75 days after transplanting recorded significantly lower density and dry biomass of monocot, dicot and total weeds. Periodically plant height, no. of umbel/plant and seed yield of fennel, and soil microbial properties were also recorded higher under these treatments. Application of FYM and vermicompost helped in buildup the bacterial, fungal and actinobacter population at all the intervals. However, positive effect of organic manure treatments was not observed on growth and yield attributes of fennel.

Effect of pre- and post-emergence herbicide on weed control and pod yield of vegetable cowpea

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Vegetable legumes are an integral part of many diets across the globe and they have great potential to improve human health, conserve our soils, protect the environment and contribute to global food security. Cowpea (*Vigna unguiculata* (L.)) is one of the most important legume which serve as vital source of protein in tropical and subtropical countries. It is one of the important kharif pulse crop grown in the India for grain, vegetable, forage and green manure purpose and commonly known as lobia. Cowpea is also called vegetable meat because of it rich in protein 19-26% (average 22.5%), carbohydrate 60.3%, minerals and vitamins. During rainy season the crop suffers severely due to weed infestation resulting into wide range reduction in crop yield. The critical period of crop weed competition in cowpea has been identified as 20-30 days after sowing and presence of weeds beyond this period causes severe reduction in yields. Hence, weed control needs to be undertaken during initial period of crop growth. Though the hand weeding is a well proven effective method of weed control, but non-availability of labour and the cost incurred in it is very high and became uneconomical. Keeping in view the fact, a field experiments comprises ten treatments (imazethapyr + imazemox at 70 g/ha (post emergence), pendimethalin at 750 g/ha (pre-emergence) *fb* quizalofop-p-ethyl at 40 g/ha (post emergence), pendimethalin at 750 g/ha (pre-emergence) *fb* clodinafop-propargyl at 60 g/ha (post emergence), pendimethalin at 750 g/ha (pre-emergence) *fb* one HW at 40 DAS, pendimethalin at 750 g/ha (pre-emergence), quizalofop@ 40 g/ha (post emergence), pendimethalin *fb* imazethapyr 100 g/ha (post emergence) weedy check, 2 HW (20 and 40 DAS), weed free (hand weeding as and when required to remove the weeds) with three replications in randomized block design was conducted for two consecutive *Kharif* seasons of 2016 and 2017 at ICAR-IIVR, Varanasi to study the effect of weed management practices on cowpea and to find out suitable and cost effective weed management practice to manage weeds during the critical period of crop weed competition. Among weed control treatments, the green pod yield was 65.3% higher with weed free than weedy check. Application of pendimethalin (pre-emergence) *fb* imazethapyr 100 g/ha (post emergence) gave 43.4 and 39.1% higher green pod yield over weedy check and quizalofop-*p*-ethyl applied at 40 g/ha post emergence at 20 days after sowing, respectively. Among various weed management options, application of pendimethalin *fb* imazethapyr 100 g/ha (post-emergence) significantly increased the yield of cowpea by controlling weeds throughout the crop season.

Integrated weed management in garlic using mulch and herbicides

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Garlic is grown for its distinctive flavour as well as its health-giving properties. Owing to slow early growth, shallow rooting behaviour, upright and narrow canopy development and poor development of canopy during its life cycle, it faces severe competition from weeds. Being a long duration crop, it is not possible to keep the weeds under check with a single method of weed control, and integrated weed management has to be employed. The integrated effect of mulching and herbicides on weeds and yield of garlic was investigated in a field study conducted during 2013-14 and 2014-15 at Ludhiana, India. The garlic cv. '*PG 17*'was planted in October and harvested in next April. The paddy straw mulch treatments (0, 5, 7.5 t/ha) were kept in main plots and weed control treatments (pendimethalin 1.0 kg/ha, oxyfuorfen 0.223 kg/ha, two manual weedings and unsprayed check) in sub-plots in a split plot design with 4 replications. The herbicide was sprayed using 500 L water/ha within 2 days of planting and mulch was spread uniformly over the entire plots afterwards. The mulch and herbicides did not influence emergence and growth of garlic. The application of paddy straw mulch at 5-7.5 t/ha significantly reduced weed density and biomass compared to without mulch. Mulch application significantly improved garlic yield and yield attributes and economic returns over without mulch; 7.5 t mulch/ha recorded significantly higher garlic clove yield and economic returns than 5 t mulch/ha. Pendimethalin, oxyfluorfen and manual weedings significantly reduced weed population and biomass and significantly improved garlic yield than unsprayed control. The integrated application of 7.5 t mulch/ha with herbicides or manual weeding resulted in the highest garlic bulb yield which was significantly higher than all other treatment combinations. Thus, integrated use of paddy straw mulch and herbicides could be adopted for sustainable weed management in garlic.

Effect of mulching and weed management practices on weed flora and yield of garlic

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Garlic (*Allium sativum* L.*)* is highly vulnerable to weed infestation due to its slow emergence and initial growth, non-branching habit, sparse foliage and shallow root system. Weed infestation in garlic is one of the major factors for loss in yield to the tune of 30 to 60%. A field experiment was conducted during *Rabi* season of the year 2016 at AICRP-Weed Management Farm, AAU, Anand to study the effect of mulching and weed management practices on weed flora and yield of garlic. The experiment was laid out in a split plot design with paddy straw mulch 5 t/ha and no mulch allotted to main plot and eight weed management practice comprises of pre- and post-emergence herbicides alone or tank mix and hand weeding in sub plot treatment with three replications.The results revealed that weed density and dry biomass of dicot and total weeds recorded at 90 DAP were significantly lower in application of paddy straw mulch 5 t/ha whereas, monocot weed density was significantly lower under no mulch treatment. Among weed management practices, pre-emergence application of oxyfluorfen 240 g/ha *fb* HW at 60 DAP recorded significantly lower weed density and weed dry biomass of monocot, dicot and total weeds at 90 DAP. Interaction effect of mulch and weed management practices was found significant and significantly the lowest total weed dry biomass at 90 DAP was recorded in application of oxyfluorfen 240 g/ha PE *fb* HW at 60 DAP with paddy straw mulch 5 t/ha. Weed control index at 90 DAP and at harvest were also higher in paddy straw mulch 5 t/ha (51% and 31%) and application of oxyfluorfen 240 g/ha PE *fb* HW at 60 DAP (99% and 91%). The plant dry biomass, number of clove/bulb and 100 clove weight recorded significantly higher in the application of paddy straw mulch 5 t/ha and pre-emergence application of oxyfluorfen 240 g/ha *fb* HW at 60 DAP. Interaction of paddy straw mulch 5 t/ha and pre-emergence application of oxyfluorfen 240 g/ha recorded significantly the higher plant dry biomass, number of cloves/bulb and 100 cloves weight.

The bulb yield of garlic was significantly higher in the paddy straw mulch 5 t/ha (6.24 t/ha) and oxyfluorfen 240 g/ha PE *fb* HW at 60 DAP (7.71 t/ha). Interaction effect of mulch and weed management practices was found significant and significantly higher bulb yield of garlic was obtained in all weed management practices under paddy straw mulch (5 t/ha) except weedy check in comparison to non-mulched treatment and among all combinations, the highest bulb yield (9.30 t/ha) was recorded in oxyfluorfen 240 g/ha PE *fb* HW at 60 DAP with paddy straw mulch 5 t/ha. Economic analysis of different treatment revealed that application of oxyfluorfen 240 g/ha PE *fb* HW at 60 DAP with paddy straw mulch 5 t/ha gave highest net return and B:C ratio (3.79). There was no any carry over/residual effect of herbicides observed on succeeding maize, greengram and pearl millet crops.

Weeds an emerging problem in high density apple orchards of shopian district of Jammu and Kashmir

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District Shopian is located on south of Kashmir and occupies an apple area of 21,666 ha. The district is known for its quality apple production. Now the progressive farmers have started shifting from traditional orchards to high density apple orchards. This new system of orchard establishment gives higher yield, quality apple production and is comparatively easy to do handle. Due to recent epidemics of Necrotic Leaf Blotch and Alternaira Lead Blotch and its least impact in high density orchards, farmers are now seriously thinking to shift to this new system of orchard establishment. Change in orchard architecture to favour dwarf root stock with shallow root system make the trees vulnerable to weed competition. Research have shown that critical period of weed competition is from bloom through mid July, when tress growth and nutrient needs are greatest. Also dense vegetation under trees act as alternate hosts for disease insect and pests. Further it increases vole habitat which can increase problem in these shallow apple trees during winter. Keeping these facts under consideration, A survey is being carried out in high density Orchards of Shopian district of Kashmir valley in 2018. From agronomic view point, weed surveys are interesting as they can perform as complement to field experiments. The time of the sampling is settled according to maximum ground cover of the crop. 1 m^2 sample area is repeated 6-7 place at each high density apple orchard by using quadrate method. The abundance of weed flora is numerated by means of frequency, relative frequency and important value index. Major weed flora observed in sampled area were *Sorghum halaense, Convolvules arvensis, Stellaria media, Chenopodium album, Amranthus viridis, Anthumus cotula, Cynodon dactylon, Melilotus indica, Fumaria parviflora, Oxalis corniculata, Rumex* spp. *etc*. Abundance percentage of *Cynodon dactylon* by means of frequency, relative frequency and important value index were 100 %, 13.99 % and 31.85. These values for *Convolvulus arvensis, Stellaria media, Sorghum halapense, Capsula bursa pastoris* were 80 %, 11.19%, 17.74; 90 %, 12.59%, 21.52; 75 %, 10.49 %, 18.23 and 80%, 11.17%, 17.74, respectively. Weed infestation is a major problem particularly in case of high density apple orchards. Some of the weeds have higher important value index. So during first year of establishment, a clean strip around trees should be maintained via cultivation or careful herbicide application. However in third year mulch can be used to increase organic matter. Use cultivation to reduce soil berms and breakup any vole habitat. The herbicides should be used judiciously to keep weed infestation below threshold level.

Management of broomrape, *Orobanche cernua* L. in solanaceous crops – eggplant (*Solanum melongena* L.)

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Broomrape, *Orobanche cernua* L. and/or *O. aegyptiaca Pers*., is a parasitic weed on several crop plants, including eggplant (*Solanum melongena* L.), and tomato (*Lycopersicon esculentum* Mill.), causing severe crop damage and yield reduction. An on farm research was conducted in Chenvelly village, Chevella mandal, of Telangana state, where in sever infestation of orobanche on tomato and brinjal to find out suitable weed management practice for management of orobanche without any phytotoxic effect on crop.

The experiment was laid out in complete Random block design, with seven treatments,*viz*. Neem cake 200 kg/ha at sowing *fb* pendimethalin 1.0 kg/ha as PE, 3 DAP *fb* soil drenching of metalaxyl MZ 0.2% at 20 DAT, neem cake 200 kg/ha at sowing *fb* alachlor 0.5 kg/ha PE, 3 DAP *fb* soil drenching of metalaxyl MZ 0.2% at 20 DAT, neem cake 200 kg/ha at sowing *fb* glyphosate 41% SL at 30 and 30 g/ha at 25-30 DAS & 55 DAT, neem cake 200 kg/ha at sowing *fb* glyphosate 41% SL at 40 and 40 g/ha at 25-30 DAS & 55 DAT, neem cake 200 kg/ha at sowing *fb* glyphosate 41% SL at 50 and 50 g/ha at 25-30 DAS & 55 DAT, application of polythene UV resistant mulch of 25 mm thickness before planting and control . Results of the on farm research revealed that application of neem cake at 200 kg/ha followed by glyphosate 41% SL at 30 g/ha at 25 and 55 days after transplanting was effective in controlling orobanche infestation while mulching with polysheet UV resistant mulch of 25 mm thickness before planting delayed emergence and lowered the incidence of orobanche resulting higher plant spread, average fruit weight, dry weight per plant and higher fruit yield while application neem cake at 200 kg/ha at sowing followed by application of higher doses of glyphosate either at 50 g/ha or at 40 g/ha at 25 and 55 days after transplanting recorded phototoxic symptoms on eggplant and application of neem cake 200 kg/ha at sowing followed pendimethalin 1.0 kg/ha as PE, 3 days after transplanting followed by soil drenching of metalaxyl MZ 0.2% at 20 days after transplanting or neem cake 200 kg/ha at sowing followed by alachlor 0.5 kg/ha PE 3 days after transplanting *fb* soil drenching of metalaxyl MZ 0.2% at 20 days after transplanting did not show any significant influence.

Studies on weed seed bank, growth pattern and management of *Trianthema portulacastrum*

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Horse purslane (*Trianthema portulacastrum*) is a serious weed in summer irrigated crops, causes severe yield reduction. Experiments were conducted at Department of Agronomy, Anbil Dharmalingam Agricultural College and Research Institute, TNAU, Navalur Kuttapattu, Tiruchirappalli to study the weed seed bank, growth pattern and management of *Trianthema portulacastrum* in garden land condition under sodic soil ecosystem during 2015-17.

Weed seed bank was assessed by germination study under pot culturing. Soil sample from various depths, *viz.* 0-5, 5-10, 10-15, 15-20, 20-25 and 25-30 cm depths were collected and used. The results revealed that higher number of seeds (162.7) was germinated under soil depth of 0-5 cm on 3rd week after soaking. At 10-15 cm soil depth, 113.3 seeds were germinated. Under deeper soil layer, minimum number of seeds was germinated (7.3 seeds in 15-20 cm, 1.3 seeds in 20-25 cm and 0.7 seed in 25-30 cm depth). Totally, 97.2% of *T. portulacastrum* seed bank was confined with the plough layer (0-15 cm) of soil. Beyond 15 cm depth of soil, only 2.8% of *T. portulacastrum* seeds were found. In sieving method, top layer of soil (0-5 cm) recorded more number of seeds (55.3 seeds/100 g of soil), followed by 45.3 seeds in 5-10 cm, 25.3 seeds in 10-15 cm and 12.7 seeds in 15-20 cm depths. Beyond 20 cm depth of soil, only 2.7% of *T. portulacastrum* seeds were found.

Growth pattern of *T. portulacastrum* indicated that it produced 24 and 37 leaves/plant at 20 and 25 DAS respectively. At 20 days, shoot and root length were 8.31 and 7.87 cm. Six times increase in dry weight was recorded from 10 days (30.59 g/m^2) to 20 days (186.3 g/m^2). It took 19 days for first flowering and 8 days for seed setting. It produced 55 capsules/plant, 383 seeds/plant in 45 days.

A field experiment on the effect of density of *T. portulacastrum* on the productivity of green gram revealed that weed free plots registered significantly higher grain yield of 737 kg/ha over *T. portulacastrum* infested plots. Even 5/m^2 of *T. portulacastrum* caused significant reduction in grain yield (16.10%) of green gram. When the number of weeds per unit increased, the grain yield of green gram was reduced drastically. The minimum grain yield of 386 kg/ha was obtained under absolute control. However, this was comparable with *T. portulacastrum* at 20/m^2 where the grain yield was 418 kg/ha. The R^2 value of linear regression between *T. portulacastrum* numbers/m^2 and grain yield of green gram was 0.95.

Field experiments on the management of *T. portulacastrum* by herbicides in green gram concluded that pre-emergence application of pendimethalin at 1.0 kg/ha on 3 DAS followed by application of imazethapyr at 50 g/ha on 30 DAS was found to be effective in controlling of *T. portulacastrum*, higher grain yield (461 kg/ha) and net profit (Rs. 14443/ha) of green gram under irrigated condition. Even though, two hand weeding at 15 and 30 DAS produced higher grain yield, application of imazethapyr at 50 g/ha on 15 DAS registered higher net returns (Rs. 9250/ha) and benefit cost ratio (1.84).

O-15

Weed management with new generation herbicides in elephant foot yam

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An experiment was conducted in elephant foot yam to find out alternatives to manual weeding and to formulate an economical weeding schedule with less harmful herbicides. The experiment was laid out in RBD with 09 treatments and 3 replications. Old, new herbicides and non-chemical methods of weed management were compared. Among the different herbicide treatments best weed control efficiency was recorded in the treatment with tembotrion (pre-emergent herbicide) + propaquizafop (post-emergence herbicide twice) was the best at 45 days after planting; the best combination at 90, 120 days after planting and at harvesting was pendimethalin (pre-emergent herbicide) + glyphosate (post-emergence herbicide twice). Plant height, canopy spread, leaf area index was highest in treatment with tembotrion (pre-emergent herbicide) + propaquizafop (post-emergence herbicide twice), the same treatment recorded lowest weed index. There was no significant difference among the treatments for microbial population indicated no residual effect of the herbicides. Significantly highest yield, gross returns, benefit cost ratio was recorded by the treatment pendimethalin (pre-emergence herbicide) + glyphosate (post-emergence herbicide twice).

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

Weed management in marigold

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The cultivation of marigold as a commercial flower crop is becoming popular among the farmers of many areas of Assam particularly in the periphery of major cities and towns. However, the long duration of the crop as well as the favorable soil and climatic conditions of the state, weeds are now ranked as one of the main growth limiting factors of this commercial crop. As no such previous research work has been conducted, a trial was proposed with the objective to evaluate and suggest a suitable weed management practice for marigold.

Methodology: A field experiment was started during the *Rabi* seasons of 2013-14 and 2014-15 in the ICR Farm of Assam Agricultural University, Jorhat with eight treatments laid out in RBD with four replications. The soils of the experimental site was sandy loam with pH 5.5, organic carbon 6.4 g/kg, soil available N 248.3 kg/ha, P 19.6 kg/ha and K 88.2 kg/ha. The marigold variety Siracole were transplanted on 09-11-2014 in plots of 3.6 x 3.0 m size.

Weed population was taken with a quadrate of 50 x 50 cm periodically from each plot and the sample was used for recording the weed dry weight. The data on weed density and dry weight was converted to per m^2. Observations on plant height, primary branches, secondary branches, flower number were taken from ten randomly selected plants and average was taken. The flower yield was taken from the harvested net plot and converted into per ha basis.

Weed population and dry weight: The lowest weed population and dry weight was obtained from the treatment with Oxadiargyl 90 g/ha followed by garden hoeing at 30 DAP which was closely followed by Hand weeding at 20 and 40 DAP

Crop growth, yield attributes and flower yield: The tallest plant with highest number of primary and secondary branches were resulted due to oxadiargyl 90 g/ha followed by garden hoeing at 30 DAP closely followed by hand weeding at 20 and 40 DAP. Improved vegetative growth finally resulted higher flower number and yield under these two treatments. However, oxadiargyl 90 g/ha followed by garden hoeing at 30 DAP was significantly superior to both of hand weeding and garden hoeing in respect of flower yield.

Table 1. Crop growth and yield attribute of marigold as affected by treatments

Treatment	Fresh flower yield (t/ha)	
Hand weeding at 20 and 40 DAP	6.70	7.22
Garden hoeing at 20 and 40 DAP	7.80	7.14
Pretilachlor 1000 g/ha followed by (*fb*) garden hoeing at 30 DAP	6.53	6.92
Oxyfluorfen 100 g/ha *fb* garden hoeing at 30 DAP	7.31	6.02
Pendimethalin 750 g/ha *fb* garden hoeing at 30 DAP	7.17	6.45
Oxadiargyl 90 g/ha *fb* garden hoeing at 30 DAP	8.33	9.12
Fenoxaprop-p-ethyl 50 g/ha *fb* garden hoeing at 30 DAP	6.63	5.57
Weedy check.	2.97	4.89
LSD (p=0.05)	0.36	0.46

Studies on allelopathic effect of *Lantana camara* (L.) and *Parthenium hysterophorus* (L.) weeds on germination and growth behaviour of *Thespesia populnea* (L.)

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To study the allelopathic potential of invasive weed species *viz. Lantana camara* (L.) and *Parthenium hysterophorus* (L.) on germination and growth behaviour of *Thespesia populnea* (L.) indigenous tree species, a pot culture experiment under greenhouse condition was conducted at Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam, Tamil Nadu during summer season (February to May) 2014. The experiment was laid out in Randomized Complete Block Design (RCBD) with treatment combination of two invasive weed species *viz*. *Lantana camara* and *Parthenium hysterophorus* and four concentration levels of aqueous extract *viz*. 10% *Lantana* aqueous extract, 20% *Lantana* aqueous extract, 30% *Lantana* aqueous extract, 40% *Lantana* aqueous extract, 10% *Parthenium* aqueous extract, 20% *Parthenium* aqueous extract, 30% *Parthenium* aqueous extract, 40% *Parthenium* aqueous extract and Control (Normal water). The results of the experiment revealed that, application of whole plant aqueous extract of *Parthenium hysterophorus* at 40% concentration level significantly reduced seed germination percentage (26.7), germination value (3.0), germination index (0.14), germination relative index (5.7) in *Thespesia* species than at lower concentration of *Parthenium hysterophorus* and *Lantana camara* weed species. Whereas, number of days required for germination of *Thespesia* seed was maximum 9.05 days in application of aqueous extract of *Parthenium hysterophorus* at 40% concentration level. *Thespesia* seedlings growth and growth behaviour were also significantly inhibited by the whole plant aqueous extract of *Parthenium* weed at 40% concentration, that recorded reduced shoot length (12.6 cm), root length (9.2 cm), dry weight (12.6 mg/plant), dry weight based vigor index (338) and chlorophyll content (15.7 µmol chlorophyll/m^2) at 60 days after sowing. To summarize, application of whole plant aqueous extract of *Parthenium hysterophorus* weed at 40% concentration level had strong allelopathic inhibitory effect on germination, seedlings growth, dry matter production and chlorophyll synthesis of *Thespesia populnea*. The sensitivity of *Thespesia* tree species to allelochemicals and extent of germination inhibition, growth reduction and chlorophyll production varied with invasive weed species and concentration levels of whole plant aqueous extract. Allelopathic potential of *Parthenium hysterophorus* may be an important mechanism involved in invasive success of this weed in natural ecosystems.

Managing weeds and improving profitability of farmer's via conservation agriculture technology

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Agriculture remains central to the Indian economy, providing livelihood to the majority of its population. Feeding a growing population with increasing dietary preference for resource intensive food product is a major challenge, faced by India today. Though, Indian agriculture have made spectacular progress for food self-sufficiency, yet growing challenges of large management yield gaps, low water and nutrient efficiency, imbalance and inadequate use of external production inputs, diminishing farm profits, deterioration of soil health, increased intensity of weeds and environmental quality coupled with climate risks are major challenges. Of the total losses caused by the agricultural pests, weeds alone contribute to as high as 37% loss in productivity. Thus, it is a need of an hour to develop strategies and practices to sustainably increase food production, while increasing farm income, protecting natural resources and minimizing environmental foot prints, for which Conservation agriculture (CA) will be proved as a milestone.

Conservation agriculture (CA) is an eco-friendly approach of farming that emphasizes on 3 basic principles *i.e.* minimal soil disturbance (zero tillage), diversified crop rotations, and surface crop residue retention (permanent soil cover). The objectives of conservation agriculture are to preserve, mend and make judicious use of natural resources through unified management of available soil, water and other biotic constituents. CA is more efficient and sustainable technology, which restore soil fertility, improve moisture conservation, increase infiltration rate, improve soil organic carbon, micro-organism activity and reducing labor needs, that ensures increased crop productivity and reduces total cost of cultivation. In conventional farming, farmers usually use tillage equipment to improve the soil structure and to control weeds. But they actually damage the soil structure and contribute to reduced soil fertility in the long term. In CA systems, however, tillage is reduced or totally eliminated. The use of CA is widely increasing in the world due to several above advantages. Along with this, various researches have proved CA to be a resource saving technology, as in comparison to conventional agriculture, CA saves 20-25% water, 60-75% machinery use, 60-75% fuel, 25-30% labour, 20-25% time, 15-20% fertilizer and 30-35% weeds. Also, 10-12 % increase in yield has been witnessed. Thus, benefit in total cost of cultivation is by approximately Rs. 5000/ha and management of weeds in also easy, *i.e.* can be done by weedicides and saves manual weeding.

Thus, it can be concluded that, CA can be an alternative in doubling farmers' income and managing the problems of weeds, by reducing the total cost of cultivation and increasing the yield and aiming at optimizing yields and profits, achieving a balance of agriculture, economics and environment.

Development and evaluation of tractor operated weeding cum earthing-up machine for effective post-emergence weed management in maize

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The maize crop culture in rainfed areas of Jammu and Kashmir agro-ecologies is being pursued mainly by the traditional practices like that of draught animal tillage followed by two hand weedings at 15 & 30 days after sowing besides all other operations like that of pre-emergence weed management devoid of any farm machinery interventions at the farm level. Weeds are one of the most important limiting factors in maize production and weed control is an important management practice that should be carried out to ensure optimum grain yield as maize is usually grown during the hot summer months when manual methods of weed control are difficult to pursue. Both the weeding and earthing-up operations in maize are time consuming and labour intensive which results in higher input cost also. Therefore, there was a need to mechanize the weeding and earthing up in maize and other broad row crops which shall result in saving of time and labour hence, a combined integrated tool, a tractor operated equipment which can perform two functions simultaneously *i.e.* weeding and earthing-up of the plants in maize rows was developed which was greatly helpful in reducing the farm drudgery as well as proving itself to be more feasible, less laborious, cost-effective and economical. The machine consisted of a mainframe with three point hitch system. Three duck foot sweeps are fixed on the front side of the three tynes fixed at mainframe followed by three adjustable ridgers just behind the tynes. The weeding was done by loosening of the top soil and uprooting the weeds. Total material and fabrication cost of the prototype was about Rs. 15,000 only. The cost of operation of equipment with tractor was Rs. 1000/ha, and it could save about Rs. 3000/ha, as compared to the traditional practice of weeding and earthing-up operation (Rs. 4000/ha). The machine's field capacity was 0.5 ha/h with about 80% field efficiency if operated at a recommended speed of 3 km/h. The machine did not only save the time of weeding and earthing-up operation but saved the labour cost also which resulted in timely weeding and earthing-up operations.

Estimation of economic loss caused by weeds in India

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Among the major biotic constraints, weeds are considered as the most harmful to agricultural production besides affecting agrobiodiversity and natural water bodies. They also affect the crop production indirectly, by competing with the crop for resources, sheltering crop pests, interfering with water management, reducing the yield and quality of grain, and subsequently increasing the cost of processing. Hence, weed management is the major and important part of crop production. Further, assessment of crop yield and economic losses due to weeds in agriculture is an important aspect of study which helps in devising appropriate management strategies against weeds. These are important figure for policy makers and researchers also. Therefore, a study was planned to reassess the yield losses (potential and actual) estimates along with economic losses by weeds affecting major field crops grown in India based on data from farmers' fields. For the purpose, data from a total of 1581 on-farm research trials conducted by AICRP-Weed Management between 2003 and 2014 in 10 major crops in different regions of India were considered. Data on yield in farmers' practice was used to estimate actual yield losses and economic losses in different crops whereas; data on weedy check was used to estimate the potential yield loss *vis a vis* weed-free situation. The study revealed that potential yield losses were high in case of soybean and groundnut crops and greater variability were observed among the yield losses in different states in case of direct-seeded rice (15-66%) and maize (18-65%). However, higher actual losses were observed in oilseeds and pulses as compared to cereals. Three factors *viz.* state, crop, and soil type significantly explained the variability in actual yield losses due to weeds. In this study, highest economic loss was observed in rice (USD 4420.42 million) followed by wheat (USD 3375.89 million) and soybean crop (USD 1559.27 million). Hence, total actual economic loss of about USD 11 billion was estimated due to weeds alone in 10 major field crops of India. In economic terms, the highest loss of approximately USD 347/ha was observed in groundnut crop with average loss of about 36% followed by maize (USD 136/ha) and soybean (USD 117/ha). However, monetary losses in wheat and rice were about USD 116 and 89/ha, respectively. So, there is need to integrate several methods of weed management including cultural, mechanical and chemical under integrated weed management (IWM) strategy for effective results. The present study considered data of 10 crops from 18 states for the assessment of economic losses due to weeds. However, data on more crops and locations may result much greater loss than what is actually estimated from the available data. Also, under changing climate scenario, weeds may get favourable environment than crops and may cause greater loss in crop production.

Enzyme and microbial dynamics of litter decomposition in water hyacinth

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Water hyacinth (*Eichhornia crassipes* (mart) solms) is the most obnoxious weed in a large variety of sub-tropical and tropical freshwater ecosystems. Management actions to control invasive aquatic species can have significant ecosystem-scale effects. We evaluated the water chemistry and nutrient effects of mechanical shredding to control water hyacinth (*Eichhornia crassipes*) in agriculture. Severe contamination of water resources including ground water with iron (Fe) due to various anthropogenic activities has been a major environmental problems in industrial areas. Hence, the use of the obnoxious weed, water hyacinth (*Eichhornia crassipes* (mart) solms) in constructed wetlands (floating aquatic macrophyte-based plant treatment systems) to phytoremediate Fe-rich waste waters seems to be an appealing option. Although several studies have documented that hyacinths are good metal-accumulating plants none of studies have documented the ability of this plant grown under different nutrient conditions to remove heavy metals from waste waters.

The litter decomposes solely by physical leaching during the initial 4 days phase, and later by microbial processes. A large number of fungi and bacteria remains associated with the decaying litter, but only a few of them are actually involved in the degradation. Bacteria are the predominant degraders, whereas fungi degrade only negligible quantities of the litter. The litter produced by the green nature plants decomposes much faster than the litter produced by the brown senescent plants. As much as 70% of the litter is decomposed by microbial processes and the reminder by non-microbial processes. Release of dissolved inorganic and organic nutrients from the decaying litter occurs chiefly by non-microbial processes. Microbes utilise only a small amount of nutrients. That are released of various elements from the decaying litter is in the order of K>P>C>Na>N. The decaying litter also releases some toxins which cause an acute toxicity to scenedesmus growth by direct interference from its initial exponential growth.

Response of decomposition rate (K) and nutrient release pattern of leaves, petioles, and roots of *Eichhornia crassipes* (water hyacinth) to different trophic conditions were studied in three wetlands located in the eastern Himalayan region. Significant differences in the hemicelluloses contents and C/N and C/P ratios were recorded in different plant parts of water hyacinth and also between wetlands. Potassium mineralisation and turnover rates were higher than that of C, N and P. In general, the turnover rates was faster in leaves and petioles of *Eichhornia crassipes*, which varied from trophic conditions studied. Roots, however, decomposed slowly (77-121 days). The K values were strongly correlated with C, N, P, C/N and C/P. Overall the higher turnover rate indicates that water hyacinth can accelerate the nutrient recycling potential in wetlands whereby the total ecosystem services could be judiciously regulated temporally. It becomes fully harness the potentials of this aquatic macrophyte, which could change its status from weed to an income-generating plant.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Weeds in Andaman & Nicobar Islands – A threat to crop and grassland (livestock) productivity and ecosystem

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Andaman & Nicobar Islands (ANI) is known for Artisanal fishing and mixed farming system. Though the contribution of primary sector to Islands GDP was low (16.2%; Rs. 830 crore in 2015-16), the livelihoods dependent (21,348, 14,839 and 68,713 cultivators, fisherman and livestock holder) on it directly makes it an indispensable component of the economy. The low external input rain fed (270-300 cm in 140 days) cropping (45,000 ha) and heavily grazing (14,840 ha grasslands) dependent livestock (53,488 bovines, 65,324 goats, 35,921 pigs) production systems contributing to over 58% primary sector GDP was subjected to several biotic and abiotic stresses. Of the biotic stresses, weeds are the most important owing to the little or no attention given for their management. The status of weed management in South and North & Middle Andaman districts was reviewed here (no weeding was followed in Nicobar district).

Homestead farming (coconut with tree spices *etc.*) on rolling topographies was highly soil erosive for whose protection, ground vegetation (especially grasses) was retained that was both nutrient (during monsoons: May- November) and moisture (in post-monsoon: December- April) depletive. The soil inversion done around tree basins in post-monsoon period for manuring did not stop the weeds from producing seed and they proliferate in perpetuity. Mulching with residues (coconut leaves, husk, shell *etc.*) was practiced with moisture conservation and weed management functions. Plastic mulching that was promoted as an inherent component of new coconut plantation development was effective for weed management. Animal grazing aids in productive use of weeds as a livestock feed. Non-selective herbicides (glyphosate and paraquat) used by few farmers only as many perceive that herbicide kill earthworms. Intensive under-storey crop cover of coconut remains the most effective weed management solution of homestead farms.

Among food crops, rainfed *Kharif* rice was rotated with pulses (mung and urd) or vegetables. Flowing and deep standing rain water brings in aquatic weed problems in addition to the normal weed of rice crop. Utility of brown manuring, conoweeding, herbicides *etc.* established through research was demonstrated to farmers. Use of weed smothering rice (C-14-8) cultivar and dual harvest (fodder and grain) for weed management were exploited by farmers. Herbicides use was low due to their varying performance in untimely rains. In vegetables, tenant vegetable farmers extensively use glyphosate/paraquat for clearing the weeds prior to planting. Tsunami of 2004 completely submerged/ high tide submerged lands were abandoned by farmers and have become aquatic weed fields.

Grasslands (upland, lowland including mangroves) productivity was severely hampered by invasive alien weeds like *Mikania mikrantha*¸ *Mimosa* spp. *Chromolaena odorata*, *Lantana etc.* The 26th December, 2004 Tsunami food aid distribution from mainland has added *Parthenium hysterophorus* to the above list. Lowered fodder production was reducing livestock production both quantity and quality wise. The protective function of weeds to sandy coasts of Islands was positive aspect of them.

In light of the Islands moving towards complete organic mode of production, utilization of weeds (aquatic weeds especially) for compost production may address the twin problems of nutrient supply for organic farms and weed management. An integrated organic weed management solutions need to be given to the farmers for various situations.

Weed dynamics and its management strategies under short rotation forestry

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Deforestation and agricultural intensification are the most important drivers of the loss of bio-diversity and associated ecosystem services. The restoration of tree-cover through agroforestry can mitigate the negative effects of deforestation and complement the protection of pristine forest ecosystems. With an increased demand of wood in the last years has raised attention in plantations stocked with fast growing trees such as *Populus deltoides, Eucalyptus* sp., *Melia composita, Prosopis cineraria* and *Salix* sp. Short rotation forestry (SRF) is one of the best options for providing higher wood yields so is a subject of research with an aim to provide improved planting material with plantation design and management.

The incorporation of trees into agro-ecosystems through adoption of agroforestry increases habitat complexity, which generally correlates positively with abundance and diversity of weed flora. Agroforestry practices may influence the occurrence and distribution of weeds via bottom-up factors such as moderation of microclimate, soil nutrients and water content. Weeds can cause severe problems in forest nurseries and commercial plantations by competing for resources like water, nutrient and light with the young trees, leading to reduced growth and survival. There is a complete change in the weed population, their abundance and distribution under agroforestry systems than sole cropping systems with the dominance of grasses and sedges like *Sorghum halepense, Cynodon dactylon, Digitaria sanquinalis, Echinochloa crus-galli, Poa annua, Setaria* spp. and *Cyperus* sp., and broad-leaf species like *Amaranthus retroflexus, Cannabis sativa, Chenopodium album, Cirsium arvense, Convolvulus arvensis, Datura stramonium, Solanum nigrum* and *Poligonum* sp.. The control of weed species to ensure maximum yield is an important element of SRF management, since the occurrence of weeds can present a significant suppression of tree-crop growth coupled with an increased rate of mortality.

For controlling the weed menace under the SRFs we generally apply the herbicides which are mainly recommended for use in agricultural crops. To design a sustainable weed management option to be adopted in agroforestry it is necessary to study about the weed communities prevailing under these systems. Accordingly, the use of non-chemical weed control strategies like silvicultural manipulation, tillage, cultivation and mechanical as well as chemical (*viz.* the use of pendimethalin, metribuzin as pre-emergence herbicide; oxyfluorfen, imazethapyr as post-emergence herbicide and glyphosate, glufosinate-ammonium) control measures can be taken up as per the persisting weed flora.

It is estimated that during the establishment year vigorous weeds were found to reduce SRF growth by 50% to 95%. So, there is a need for a sensitive integrated weed management (IWM) approach with a better awareness of weed-crop relationship including greater familiarity with methods of weed control, weed growth habits and seed bank dynamics which will pave way towards development of optimal weed control procedures with an efficient and targeted use of herbicides providing economical and ecological benefits to grower, the product end user and wider population.

Phytosociological analysis of *Parthenium hysterophorus* and its management through competitive weeds

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The city of Mumbai, which is the capital of the state of Maharashtra, is situated on the Indian subcontinent's western shore brushing the Arabian Sea. The urban expanse, which nowadays constitutes the city of Mumbai, is comprised of seven islands. Mumbai is based on the Salsette Island that is located at the opening of Ulhas River, in the coastal region known as Konkan. It covers the total area of 603 square km. The average temperature is 27.2^0C and average precipitation is 243.2 cm. The mean maximum temperature is about 35^0C in summer and 30^0C in winter, while the mean minimum temperature is 25^0C in summer and 20^0C in winter. *Parthenium hysterophorus* is one of the most aggressive invaders of natural plant diversity. It starts growing in patches and gradually dominates and replace accompanying flora, resulting into huge *P. hysterophorus* infestations. Within last 10 years it has become one of the seven most dangerous weeds of the world. It is an aggressive invader of disturbed and degraded land, rapidly displacing native and planted pastures. In addition to reducing land productivity, the plant causes acute allergic dermatitis and rhinitis in susceptible humans. *Parthenium* contains sesquiterpene lactones which induce several allergic reactions in susceptible individual who are continuously exposed. It has been declared a national health hazard in view of its serious skin allergies to man and animal. In India, 4-7 per cent of human population suffers from recognizable clinical symptoms associated with *Parthenium*, while 42-52 per cent is sensitized without showing symptoms.

To know the present status and impact of *P. hysterophorus* infestations on other plant communities, a seasonal vegetational survey was conducted at *P. hysterophorus* heavily infested sites in Mumbai district during the year 2016-17. Total 11 plant species were recorded from two different sites of Mumbai district which were heavily infested with *P. hysterophorus* during monsoon season. Among all the plants, *P. hysterophorus* was found to be the most dominant and abundant weed throughout the season and sites with maximum ecological indices. Some plant species like *Cassia occidentalis* and *Calotropis procera* showed their remarkable presence along with *P. hysterophorus.* In seedling bioassay test *Parthenium* seedlings were raised in plastic pots containing sterilised soil, sand, and peat (1:1:1) and placed at room temperature. These seedlings were sprayed with shoot leachates of 50% and 100% concentrations of *Cassia occidentalis* and *Calotropis procera*. Observations regarding the toxicity of the seedlings were made after 24, 48, and 72 hours. Phytotoxic damage was recorded on the basis of rating scale of 0-4; where 0 = no effect, 1 = slight chlorosis, 2 = marked chlorosis, 3 = drooping of seedlings, and 4 = death of seedlings. These results clearly established the fact that allelopathic potential of these competitive weeds can be utilized for the management of *Parthenium* because these agents could exert allelopathic impact and hinder germination and growth of *Parthenium*. This method of control will also lead to a reduction of applied herbicide; hence, the soil environment might be kept aside from possible detrimental effects caused by synthetic agro- chemicals.

Management of cross resistance in *Phalaris minor* against recommended herbicides in wheat

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Phalaris minor is the dominant and troublesome grass weed of wheat in rice-wheat cropping system in the north-western Indo-Gangetic plains of India. After evolution of resistance in *P. minor* against isoproturon in the early 1990s, four new herbicides (clodinafop, sulfosulfuron, fenoxaprop and tralkoxydim) were recommended in resistance affected areas of rice-wheat cropping system. Complaints of poor efficacy of these alternate herbicides started appearing at farmers' fields after their continuous use. Even the repeated application of these herbicides or their application at higher doses failed to provide satisfactory control of resistant population of *P. minor*. The use of herbicide mixtures or their sequential application can be investigated to chalk out an effective strategy for the management of resistant *P. minor*. Hence, present investigation was conducted to evaluate the potency of different herbicide mixtures and their sequential application for control of resistant *P. minor* in wheat.

To study the efficacy of different herbicides against resistant *P. minor*, a field experiment was conducted during *Rabi* 2017-18 at Agronomy research area, CCS HAU, Hisar. The treatments included PRE application of pendimethalin 1500 g/ha and mixture with metribuzin 175 g/ha alone, pendimethalin + pyroxasulfone (TM) at 1500 + 102 g/ha alone and their sequential application with POE mesosulfuron + iodosulfuron (RM) 14.4 g/ha and pinoxaden 60 g/ha. The experiment was laid out in a randomized block design. Herbicides were sprayed with knapsack sprayer fitted with flat fan nozzle using water volume of 375 L/ha. Wheat cultivar HD 2967 was sown on 19 th November, 2017 at a row spacing of 20 cm using seed rate of 100 kg/ha.

Pre-emergence application of pendimethalin or metribuzin was not much effective against resistant population of *P. minor* with only 33-35% control. Although pre-emergence application of pendimethalin + metribuzin (TM) at 1500 + 175 g/ha increased control of *P. minor* but was not sufficient to control second flush of weeds appeared after first irrigation to satisfactory level with only 53.3% control. Pre-emergence application of pendimethalin + pyroxasulfone (RM) at 1500 + 102 g/ha either alone or followed by sequential use of pinoxaden 60 g/ha/, meso + iodosulfuron (RM) 14.4 g/ha at 35 DAS caused significant reduction in density of *P. minor* and provided 83-93% control of *P. minor*. Pre-emergence use of pendimethalin + metribuzin in conjunction with post-emergence herbicides provided 60-68.3% control of *P. minor*. None of herbicide treatment except tank mixture of pinoxaden and metribuzin at 50 + 120/150 g/ha and pendimethalin + metribuzin (before sowing) at 1500 + 175 g/ha caused any phytotoxicity on wheat. Pre-emergence application of pendimethalin + metribuzin (before sowing) at 1500 + 175 g/ha (before sowing) caused 5% reduction in wheat germination affecting no. of tillers/m^2 and significant reduction in grain yield. Maximum weed control efficiency (83-93% at 30 DAT and 87-88% at 60 DAT) was obtained with pyroxasulfone treatments which had a reflection on number of tillers/m^2 and grain yield of wheat.

Maximum seed yield (5.8 t/ha) was obtained with use of pendimethalin + pyroxasulfone at 1500 + 102 g/ ha *fb* sequential use of pinoxaden 60 g/ha with 88.7% control of *P. minor* which was at par with weed free check, pendimethalin + pyroxasulfone at 1500 + 102 g/ha *fb* sequential use of meso + iodosulfuron (14.4 g/ha) and pendimethalin + pyroxasulfone at 1500 + 102 g/ha alone.

Strategic development of herbicide to combat the massive problem of *Phalaris minor* weed, through computational approach

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Phalaris minor is the most disquieting grass weed of wheat crop which resistivity against isoproturon was first reported in early 1992, later its application was withdrawn. Thereafter, alternate herbicides were introduced but *P. minor* again has developed resistance against alternate herbicides also. Therefore, development of a novel herbicide to control *P. minior* and regain wheat grain production has great importance. The herbicide isoproturon binds to the D1 protein of photosystem II (PSII) at QB binding site and thus hamper the electron flow there by inhibit photosynthesis. Earlier we have synthesised eighteen isoproturon analogs, among which triazole derivative of isoproturon was effective but it has shown poor specificity toward the weed. That can be due to D1 proteins of *P. minor* as well as of wheat are evolutionary conserved. Thus, it has become a major challenge to develop selective herbicide against weed D1 protein.

In order to design and develop potential herbicides against D1 protein of PSII, computational approaches have been used. The computational methods implemented for this study embraces modelling of D1 protein, retrieval of molecules from open source database, e-pharmacophore generation, virtual screening, molecular docking of hit compounds, in silico Absorption Distribution, Metabolism, Excretion and Toxicity (ADMET). Three data sets have been screened to obtain potentially effective herbicide; namely: 1. dataset including of all the molecules from C1, C2 and C3 class of herbicides, 2. dataset comprising molecules from Phase database, lastly 3. analogues of C1, C2 and C3 herbicides obtained from ZINC12 database.

Further, based upon the already known reference herbicides isoproturon, methabenzthiazuron and metoxuron, a four featured and a three featured e-pharmacophore has been simulated. Further, all molecules of C1, C2 and C3 class of PSII inhibiting herbicides has been retrieved. Upon screening those on the basis of three featured pharmacophore 34 hit molecules have been identified. Three feature e-pharmacophore have been established and identified the 9000 hit molecules (focused library) from phase database. This focused library has been further put through molecular docking studies (HTVS, SP and XP algorithm; respectively). Molecules were further subjected to ADMET test to narrow down the list. The obtained molecules have been again screened against four feature e-pharmacophore and 27 hit molecules have been prioritised. Analogue of C1, C2 and C3 retrieved from ZINC12 database has been used and formerly mentioned protocols has been followed to narrow down the list to 108 molecules from the pile of 3554 molecules.

Finally, 169 hit molecules have been filtered out from various databases through different protocol and stringent filtering criteria for seed assay in laboratory controlled condition, pot assay as well as field trial to execute and obtain real time evidence of the theoretical study.

Exploiting herbicide resistance related fitness costs for managing herbicide resistant weeds

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Herbicides have been the most effective weed control tool, killing 90 to >99% of the target weeds. However, the use of routine herbicide applications to control weed population imposes continuous selection pressure which can lead to the evolution of herbicide resistance. Presently, herbicide resistance has been reported in more than 240 weed species, including resistance to almost every known herbicidal mode of action. Multiple herbicide resistance being reported in *Phalaris minor* in Northern India is one such example, which may endanger the wheat productivity in absence of proper control. Resistance mechanisms often provide fitness advantage to weed in the presence of herbicide. Similarly, for plant defence mechanisms, resistance mechanism results in altered vital proteins (in target site resistance) and/or secondary metabolic pathways (in non-target site resistance). It has been widely accepted that such adaptations may incur a cost when plants are not challenged by the stress, to which they have adapted; this cost is known as fitness cost for adaptation. Similarly, herbicide-resistance mutations may impose a fitness penalty in herbicide-free environments, which has been reported in some studies for several modes of action. This can be associated with the fact that it alters the natural function of important biological processes in plants. However, the fitness penalty associated with herbicide resistance is not a stable parameter and can be influenced by ecological factors. One type of such antagonistic pleiotropic effect is increased sensitivity to other herbicides (often termed as negative cross-resistance). With some exceptions, this negative cross-resistance has been rarely observed in weeds. Pleiotropic effects of herbicide resistance generally affect physiological and developmental processes in plants. Such affects cannot be reliably assessed as they vary with genetic background and environmental conditions. It has also been suggested in some studies that fitness penalties may be more evident under stressful environmental conditions. For example, the deleterious effect of an acetyl CoA carboxylase allele (responsible for resistance mechanism against ACCase inhibiting herbicides) on vegetative and reproductive output of weeds differed significantly among populations and were more pronounced under limiting environmental conditions. These fitness costs even vary with resistance gene and sometimes with target site resistance allele. For instance, fitness effects associated with the acetohydroxyacid synthase allele Trp-574-Leu, (which confers target site resistance to ALS inhibitor herbicides) varies from major reduction in biomass and competitive ability to no visible effect. Deleterious effects of resistance are not always strong, which explains why resistance can persist in weed populations for years after the removal of any herbicide selective pressure. Most of the published studies on fitness costs, only investigated part of the life cycles of weed species (e.g., vegetative growth and seed output, or seed germination). However, complete understanding of the pleiotropic effects of herbicide resistance requires investigation on the entire weed life cycle. Proper estimation of fitness costs is the initial step for the identification of evolutionary constraints. Only then, this penalty in terms of changes in morphological parameters of Susceptible and Resistant biotypes; reduced germination, viability, competitive ability with crop and seed production potentials, can be exploited for weed management in different scenarios of herbicide selection pressure.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Current status of herbicide resistance in *Phalaris minor* Retz. in Haryana

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Residue management and herbicide resistance in *Phalaris minor* Retz. in wheat are the major sustainability issues, putting the rice-wheat cropping system in Indo-Gangetic Plains under serious threat. Herbicide resistance is a productivity issue for which farmers are looking towards weed scientists for integrated management strategies. Resistance was reported against isoproturon in 1992-93 and alternate herbicides (clodinafop, fenoxaoprop, sulfosulfuron and tralkoxydim) were recommended to combat resistant *P. minor* in 1997-98. These alternate herbicides served the purpose for 10-15 years but from last 5-10 years, these herbicides are also showing poor efficacy. Researchers have reported multiple/cross-resistance in *P. minor* against alternate herbicides also.

Many field surveys were conducted to assess the status of resistance in *P. minor* but these were random in nature. Hence, an extensive survey with systematic approach was conducted in *Rabi* 2018 in five districts (Yamunanagar, Kaithal, Karnal, Fatehabad and Rohtak) of Haryana. Two blocks were selected from each district and three villages from each block and a total of 300 farmers were covered from 30 villages involving 10 farmers from each village.

The study revealed that at present farmers of Haryana are back to square one similar to 1990s and ano herbicide is satisfactorily effective against *P. minor*. Farmers are using every possible combination of herbicides in a hit and trial way and applying herbicides 3-4 times than the recommended dose and still not getting desirable control. Farmers in Karnal are applying more than four times and in Kaithal three and half times than the recommended/X-doses of different herbicides. Overall, the farmers in Haryana are applying about three times herbicides and still getting only 70-80% control.

Farmers accept that clodinafop is not showing any result but still it is contributing about half of the total herbicide use. Whereas, sulfosulfuron and pinoxaden contributed one-fifth and mesosulfuron + iodosulfuron (ready-mix) contributed <5% to total herbicide use. Mesosulfuron + iodosulfuron provided good control, but farmers are afraid of it due to phyto-toxicity in wet conditions or overlapped repeat spraying. Recently, farmers have started using pendimethalin (750-1000 g/ha) as pre-emergence and metribuzin as post tank-mix (50-140 g/ha) with alternate herbicides to get desirable results. Even, farmers are doing their own experiments and few farmers applied metribuzin (175-350 g/ha) at first irrigation by mixing with urea and found satisfactory control. Farmers also reported that zero-tillage reduced *P. minor* infestation to the extent of 15-20% but some felt that after few years they again encountered with same problem.

More than 90% of farmers are using 225-300 litres of water/ha instead of 500 and are using flood-jet or cut nozzles instead of flat-fan nozzle. Most of farmers apply herbicides later than 40 days after sowing. All these factors further reduced herbicide efficacy. About half of farmers blamed that herbicides were poor in quality and rest believed that resistance has evolved due to mono-cropping, high use of nitrogenous fertilizers and over-dose of herbicides. Farmers also blamed *basmati* rice and lease system for speedy development of resistance. Overall, farmers are in terrible situation and spending lot of money to combat this dreaded weed in rice-wheat cropping system of Haryana. Farmers are of the opinion that there is a yield reduction of more than two t/ha due to resistant *P. minor* and the problem is getting more complicated year by year.

Agronomic evaluation of herbicide tolerance in chickpea genotypes

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Globally, chickpea (*Cicer arietinum* L.) is an important food legume, and is presently grown in more than 55 countries across 5 continents and traded by more than 150 countries. Chickpea, the major pulse crop of India, accounting for about 40.5% (9.38 MT) of total pulses production (23.13 MT) from nearly 32.7% of area (9.38 Mha) under pulses (29.44 Mha). Until 2002-03, its production was stagnant at around 3-5 MT, which has increased to 9.38 million tonnes (MT) in the year 2016-17 and further increased to 11.10 MT during 2017-18 as per advance estimates of the GOI. In India, chickpea productivity has shown impressive positive trend when per ha yield increased from 802 kg/ha (2002-2007) to 2012-17 (944 kg/ha) and 1091 kg/ha (2017-18). Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, Karnataka, Andhra Pradesh, Chhattisgarh, Jharkhand and Bihar contributes > 95% of the total chickpea production. Chickpea is known to poor competitor of weeds especially during the initial growth stages. Moreover, it is also sensitive to most of the post-emergence herbicides known to control seasonal weeds during winter season, therefore, choices for using post-emergence herbicides are limited. The present study was aimed at identifying chickpea genotype (Desi or Kabuli) tolerant to two herbicides with different modes of action (imazethapyr-amino acid synthesis inhibitor; and carfentrazone-ethyl -protoporphyrinogen oxidase inhibitor) at different levels of application concentrations. Under the experimentations, chickpea genotypes viz; '*Shubhra*', '*JG 16*' and '*Ujjawal*' were tested under varying herbicide treatments *viz.* carfentrazone-ethyl at 20 and 30 g/ha, imazethapyr at 50 and 75 g/ha for herbicide tolerance, phytotoxicity and weed density. Application of carfentrazone-ethyl at 30g/ha had highest phytotoxicity in '*JG 16*' (94.33%) followed by carfentrazone-ethyl at 20 g/ha, imazethapyr at 75 g/ha and imazethapyr at 50 g/ha. Least phytotoxicity was noticed in '*Ujjawal*' with the application of imazethapyr at 50 g/ha. Moreover, spray of both the herbicides carfentrazone-ethyl (20 and 30 g/ha) and imazethapyr (50 and 75 g/ha) had phytotoxicity in the chickpea plants. Further, toxicity level was more in desi type chickpea compared with kabuli type. Variations in weed density at 75 days after sowing of chickpea were also differed markedly due to application of different herbicides at variable doses. Application of carfentrazone-ethyl at 30 g/ha recorded least density of *Cyperus rotundus* (6.39/ m^2), followed by imazethapyr at 75 g/ha (6.44/m^2), carfentrazone-ethyl at 20 g/ha (7.62/ m^2) and imazethapyr at 50 g/ha (9.29/m^2). However, least weed density of *Coronopus didymus*, *Oxalis latifolia*, *Argemone Mexicana* and other weeds were observed with the application of imazethapyr at 75 g/ha. This might be due to more toxicity effect of imazethapyr on these weeds compared with carfentrazone-ethyl. Among chickpea genotypes, higher weed density of *Cyperus rotundus* was noticed in desi type chickpea (*JG 16*) compared with kabuli type (*Shubhra* and *Ujjawal*). Further, weed density of *Coronopus didymus*, *Oxalis latifolia*, *Argemone mexicana* and other weeds were not affected due to genotypes.

Resistance to imazethapyr in commelina biotypes in soybean growing central India

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Soybean [*Glycine max* (L) Merrill] is an important crop grown in many parts of central India. Being a rainy season crop, it suffers severely due to weed infestation causing a reduction in the yield of soybean from 58-85%, depending upon the types and intensity of weeds (Kewat *et al.* 2000). Long-term use of a single herbicide may lead to the development of resistance in targeted weeds (Singh *et al.* 2014). There are many factors that interact and influence the weed population dynamics in soybean cropping system. Changes in tillage practices, cultural practices such as soybean row spacing and planting date, and weed management practices have all had an impact on the weed spectrum. There are currently 495 unique cases of herbicide resistant weeds globally, with 255 species (148 dicots and 107 monocots). Weeds have evolved resistance to 23 of the 26 known herbicide sites of action and to 163 different herbicides. Herbicide resistant weeds have been reported in 92 crops in 70 countries. Total of five cases of herbicide resistance has been reported from India in two weed species (*Phalaris minor* and *Rumex dentatus*). *Phalaris minor* has evolved multiple herbicide resistance (MHR) across three modes of action: photoynthssis at photosystem II site A, acetyl-coA-carboxylase (ACCase) and acetolactate synthase (ALS) inhibition. A recent case of herbicide resistance in India has been reported in *Rumex dentatus* against ALS (metsulfuron) (Chhokar 2014). To evaluate the selection pressure of Imazethapyr for *Commelina* sp. in soybean, we have surveyed of 13 soybean growing districts of Madhya Pradesh, *viz.* Indore, Ujjain, Dhar, Mandsaur, Rajgarh, Shajapur, Damoh, Sagar, Ashok Nagar, Dewas, Harda, Sehore and Hoshangabad. Simple random sampling was used to collect the weed seeds under study. Only physiologically mature seeds were collected. Seeds were collected from 5-7 locations in each field and bulked together to make single sample. The GPS coordinates were noted down at every location throughout the survey. A total of 38 seed samples of *Commelina communis* and *Commelina benghalensis* were collected. We have collected the samples by interacting with the farmers, where imazethapyr efficacy was less. During *Kharif* 2017, the collected seeds of *Commelina* spp. (38 biotypes) were sown in plastic pots of 20 cm diameter and 22 cm height. The pots were filled with field soil and arranged in completely randomized block design and replicated thrice. The tested herbicide (imazethapyr) was applied at 100, 200 and 400 g/ha at 4-5 leaf stage of *Commelina* biotypes. For confirmation of the resistance of biotypes, the harvested seeds from previous season were again tested in *Kharif* 2018. *Commelina* biotypes out of 13 districts, only the biotypes of three districts, *viz.* Indore, Damoh and Dewas showed resistance against imazethapyr at recommended dose (100 g/ha). But, biotype of Dewas district exhibited higher level of resistance against imazethapyr *i.e.* 400 g/ha.

Weed management in organic agriculture

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Modern agriculture heavily depends upon chemical fertilizers and pesticides. Organic agriculture is being proposed as an alternative agriculture to offset the ill-effects of conventional agriculture where chemical fertilizers and pesticides are used to obtain higher crop productivity. Organic agriculture is a holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. This is accomplished by using, where possible, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfill any specific function within the system. (FAO/WHO Codex Alimentarius Commission 1999). The total area in India under organic certification process (registered under National Programme for Organic Production) is 3.56 million hectare (2017-18). This includes 1.78 million ha (50%) cultivable area and another 1.78 million hectare (50%) for wild harvest collection.

Managing weeds organically as well as sustaining higher crop productivity is a major challenge in organic systems. Synthetic herbicides, defoliants and desiccants are not permitted in organic systems. Unlike herbicide use in conventional farming, weed management in organic agriculture mainly relies on management techniques, both cultural and mechanical, developed to prevent infestation of weeds along with growing a vigorous crop which is able to compete with the weeds.

The weed control strategies for organic crops are based on the principles of prevention, tillage, stale seedbed, crop rotation, competitive crop varieties, intercropping, planting geometry, mulches, smoother crops, soil solarization, nutrient and water management, efficient weeding tools and machinery, biological weed control *etc.* Studying the long-term effects of these management practices on weed seed bank and weed shifts in the organic fields is important for the sustainability of the organic systems.

Results of field experiments conducted at ICAR-DWR have proved the benefits of black polyethylene and crop residue mulch in vegetable crops, maize and turmeric; intercropping with *Sesbania* for 30 days in rice, intercrop of blackgram in maize, green leaf (*Glyricidia*) mulch in maize and turmeric, crop residue mulch and hand weeding in chickpea for managing weeds and obtaining optimum crop productivity.

The researchable issues on weed management in organic agriculture may include studying the weed biology, weed seed bank in soil and weed shifts; finding suitable crop rotations to smother weeds; conventional and zero-tillage practices; making changes in crop sowing dates to disadvantage of weeds; exploiting weed competitive crops and allelopathic effects on weeds; effect of mulches and cover crops for weed suppression; development of efficient weeding tools/machinery, development of robotic weed killer machines; biological weed control, among others.

Exploring allelochemical producing cover crops for weed management in cotton

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Allelopathy, a sub-discipline of chemical ecology is an approach to affect the growth, development and distribution of other plants in nature. In agricultural systems, allelopathic research is mainly based on screening the crop plants for the identification of allelochemicals and their capacity and efficiency to suppress the weeds. Our study, was planned and executed by growing various cover crops in the inter-row spaces of rain-fed cotton (*Gossypium hirsutum*) grown on the Vertisols to suppress weeds. Various cover crops included cereals, legumes, oilseeds and aromatic plants and were evaluated over six seasons (2012 to 2017). The inter-row cover crops were mulched ca. 45 days after sowing. Weed density was recorded in all the cover crop treatments *vis-a-vis* the weedy check and the weed free treatments. In general, the cover crop treatments resulted in a reduction in weed numbers per unit area. However, the cover crop treatments of sunflower, sorghum, sunnhemp and pearl millet brought about the most significant reduction in weed density as well as weed biomass m^{-2} compared to the other cover crop treatments. Weed density reduction ranged from 25.5 to 212.4% over the weedy check treatment. Some of these select cover crops were collected, extracted using methanol extracts and the extracts were analysed using the GC-Mass Spectrometer. The different compounds were identified. Broadly, the compounds belonged to either or a combination of the fatty acids and their derivates such as terpenes, sterols, aldehydesand aliphatic hydrocarbons. The most prominent, in terms of abundance, in the select cover crops were: (i) sorghum - phytol and pentadecanoic acid, 1,4 methylene methyl ester; (ii) pearl millet - 9,12-octadecadienoic acid (Z,Z)-, methyl ester and neophytadiene; (iii) sunnhemp - squalene and linolenic acid; (v) marigold - quinic acid and decanal; (vi) bitter cumin - gamma sistosterol and octatricontnyl pentafluropropionate; (vii) beggar weed - 9,12,15 - octadecatrienoic acid and stearic acid methyl ester; (viii) carom - gamma terpinene and heptacosanal; (ix) fennel - limonene. Most of these chemicals are reported to have allelochemical properties. To summarize the field studies indicated efficacy of cover crops in reducing weed density and showed the presence of allelochemical compounds present in them that may have contributed to significant reduction in weed density. As a future line of work, these identified allelochemicals need to be tested either separately or in forms of their respective plant extracts for field efficacy.

Preliminary characterization of primary and secondary metabolites of *Alternaria raphani* J.W. Groves & Skolko as bioherbicide against *Alternanthera philoxeroides* (Mart.) Griseb

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Alligator weed, *Alternanthera philoxeroides* (Mart.) Griseb. (Amaranthaceae), one of the world's most invasive species, affects both aquatic as well as terrestrial ecosystems. Classical methods of control, like manual abstraction have been outpaced by its rapid rate of vegetative reproduction. Negative impacts of chemical herbicides and the laborious and expensive mechanical processes have led to the improvisation of biological control of the invasive alligator weed. Incorporation of a flea beetle, *Agasicles hygrophila* Selman and Vogt (Coleopteran: Chrysomelidae), a moth, *Vogtia malloi* Pastrana (Lepidoptera: Pyralidae) and a thrips, *Amynothrips andersoni* O'Neill (Thysanoptera: Phloeothripidae) as potential biological control agents, have been successful in delimiting the infestation to some extent. Other than arthropodal agents, fungal phytopathogens like *Alternaria alternantherae*, *Fusarium* sp and *Colletotrichum* sp. have also been studied as potential biological control agents.

Our current study, involves isolation of an indigenous phytopathogen, *Alternaria raphani* J. W. Groves & Skolko, from infected *A. philoxeroides* leaves, collected during field survey. The fungus has wide temperature tollerance (7-37^{o}C), proving it to be a useful even for field conditions in India where temperatures reaches extreme during summer. The fungi grew well in wide pH range with best growth in highly alkaline condition. Richard's Agar and Malt Agar supported best growth in both solid state fermentation and submerged fermentation. The stability of the fungus in varying environmental conditions, hints at the long shelf life and extended span for metabolite production. Fungal metabolites being a bio-friendly alternative to synthetic hazardous chemicals, are exploited in areas like agriculture, pharmacy, *etc.*, that are beneficial for the ecosystem and eventually ecological balance.

The secondary metabolite, produced from *A. raphani*, have a narrow host-range, with extremely phytotoxic results against the weed. It is thus considered as a potential mycoherbicidal agent against *A. philoxeroides.* The bioassay results showed that the metabolite obtained significantly inhibited the growth of the test weed even at 100 ppm concentrations by 7th day of application. Further primary metabolites in form of different sets of lytic enzymes were produced by *A. raphani*. The fungi yielded xylanase (EC 3.2.1.8) and endoglucanase (EC 3.2.1.4) group of enzymes. Both the enzymes shows a quick activity, with endoglucanase showing it best activity within 24 hours, and xylanase within 48 hours, after which the activity drops due to exhaustion of the available nutrients. All fungi do not necessarily produce secondary metabolites usable as bioherbicides against weeds. Primary metabolites, play an important role in the hydrolysis of plant cell wall material, which is a formidable task because of the complexity of the plant cell wall. In most, currently deployed cellulosic ethanol plants, enzyme cocktails containing multiple classes of cell wall- or polysaccharide-degrading enzymes (CWDEs) are used to hydrolyze plant biomass into fermentable sugars. Understanding the function, synergy, and stability of enzymes is thus of paramount importance for proper maintenance of their activity. Though lot of studies including identification of the bioactive compounds, their stability under wide range of environmental conditions, impact on non-target organisms, *etc.*, still remains to be done.

Smicronyx lutulentus, the seed-feeding weevil, to control *Parthenium hysterophorus* in India: protocols followed for its import, quarantining and pre-release studies

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Parthenium hysterophorus or parthenium weed is an aggressive annual herbaceous weed with considerable presence in several regions, including Africa, Australia, Asia and the Pacific Islands. In India, it is often found along roadsides, railway tracks and irrigation channels, on abandoned land, in residential layouts and on agricultural farms causing great threat to environment, agriculture, biodiversity conservation, and human and animal health.

Biological control of parthenium was initiated in the 1980s with the introduction of *Zygogramma bicolorata*, the Mexican beetle. The insect is now found in different parts of the country, as it has been either released deliberately or spreading on its own. Seasonal availability of the beetle (June/July), hibernation during winter and feeding only on leaves are its limitations. The scale of this weed problem, however, demands additional biocontrol agents to satisfactorily manage it. Though two rust-causing fungal pathogens were also evaluated against Indian parthenium weed populations under quarantine conditions in UK, they have not been introduced so far.

Recently, the seed-feeding weevil, *Smicronyx lutulentus*, a native of Mexico and Texas, USA, was chosen for importation. The rationale for considering import of this agent for India is its host-specificity besides its soil-inhabiting nature and effect on checking seed production. It has shown excellent suppressive effect on parthenium weed in Queensland, Australia, and has been found to be promising in South Africa.

On 24 April 2018, the first shipment of 90 adult *S. lutulentus* were received from Biosecurity Queensland, and subsequently another consignment of 30 adults were received on 27 September 2018. The weevils underwent quarantine screening in the QC-2 facility at the ICAR–National Bureau of Agricultural Insect Resources, Bengaluru. The adult weevils had an extended longevity of 157 days as documented from the preliminary studies conducted. Standardisation and refinement of rearing techniques in the Indian context and host-specificity testing of closely-related native and economically important flora are under way. Host plant studies conducted in Australia and South Africa indicate that *S. lutulentus* does not attack other plants. Field-release permit will be obtained for limited releases in indentified localities after the completion of host-specificity studies. This paper provides all the protocols and procedures followed for import, quarantining and pre-release studies.

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Recent advances and new innovative approaches in *Parthenium hysterophorus* management using mycoherbicide

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Parthenium hysterophorus L., of the family Asteraceae is an erect and much branched annual or ephermeral herb, known for its notorious role as environmental, medical, and agricultural hazards. It is believed to have been introduced into India and Australia from Central America and in the last few years the weed has emerged as the seventh most devastating weed in Africa, Asia, and Australia. Weed management through chemical herbicides creates spray drift hazards and adversely affects the environment. Besides, herbicide residues in food commodities, directly or indirectly, affect human health. These effects lead to the search for an alternate method of weed management which is eco-friendly. In this regard, biological approaches are gaining momentum. They include a high degree of specificity to target weed, with no effect on non-target and beneficial plants or man, absence of weed resistance development, and absence of residue build-up in the environment. Currently, fungal weed control is rapidly developing natural phenomena in research areas with implications for plant yield and food production. Fungal weed control may help to maintain the quality of crops and reduce the use of chemical pesticides and other toxic chemicals and offer important natural mortality factors for weed population control under natural environmental conditions. The application of the fungal spores, fermented broth, and their crude metabolite or purified metabolites is a very good source for natural herbicide for the management of *Parthenium* weed. Fungal weed pathogens can produce a wide array of toxins, bioactive metabolites with different biological activities, chemical structures, mechanisms of action, specificity with respect to plants, and environmental impact and stability. This paper will discuss the current research progress on fungi and their secondary metabolite application for the management of *Parthenium* weed.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Effect of mulches and weed management on unpuddled transplanted hybrid rice

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A field experiment was conducted during *Kharif* season of 2017 at Agriculture Research Farm, Institute of Agricultural Sciences, BHU, Varanasi, to study the effect of mulches and weed management on unpuddled transplanted rice. The experiment was laid out in a split plot design with three mulching treatments *viz.*,without mulching, cover crop of *Sesbania* followed by surface mulch with same residue and rice straw mulch (5 t/ha) in main plots and five weed management treatments, *viz.*, weedy, hand weeding at 20 and 40 DAT, post-emergence application of bispyribac 25 g/ha at 18 DAT, post-emergence application of penoxsulam 30 g/ha at 18 DAT and post-emergence application of bispyribac 25 g/ha and pyrazosulfuron 20 g/ha at 18 DAT in sub plots. The experimental site was homogeneous in fertility with even topography, uniform textural make up having assured irrigation and other required facilities. *Sesbania* was sown as a cover crop, 45 days before the transplanting with therow spacing of 25 cm at seed rate of 25 kg/ha and incorporated manually at the time of transplanting and rice straw mulching (5 t/ha) was done after transplanting as per treatment. The field was prepared in dry conditions by tilling the land conventionally there after transplanting of rice seedling was done by irrigating the field. Rice cultivar Arize 6444 was transplanted on 20th July 2017. A uniform dose of 160 kg/ha N, 60 kg/ha $P_2O_5$and 60 kg/ha K_2O was applied in all the plots. Half dose of nitrogen and full dose of phosphorus and potassium was applied as basal and rest half of N was applied in two equal splits, at active tillering and panicle initiation stages. The main dominant weeds in the field were *Echinochloa colona*, *Echinochloa crusgalli*, *Cyperus rotundus*, *Cyperus difformis* and *Cyperus iria*. Narrow-leaved population was more as compared to broad-leaved weeds. Results indicated that mulching with *Sesbania* provided effective control of weeds and recorded significantly higher grain yield than no mulch, and it was at par with the rice straw mulch (5 t/ha). Among weed management treatments post-emergence application of penoxsulam 30 g/ha resulted in significant reduction in density and dry matter of weeds and increased grain yield followed by post-emergence application of bispyribac 25 g/ha and pyrazosulfuron 20 g/ha and post-emergence application of bispyribac 25 g/ha. Treatment combinations of surface mulching with *Sesbania* and two hand weeding recorded significantly higher grain yield (7.1 t/ha) as compared to other treatment combinations, followed by combination of surface mulching with *Sesbania* and post-emergence application of penoxsulam 30 g/ha (7.0 t/ha), which was at par with former treatment.

Impact of biocontrol agents on biochemical changes of aquatic weed water hyacinth, *Eichhornia crassipes* (Mart.) Solms-Laubach

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Plant–micro organism–arthropod interactions can influence the plant defence response through a range of chemical responses influence arthropod behaviour or pathogen infection, leaving a cumulative impact on the biological control of the weed. Invasive weeds, due to the augmentative release of multiple biocontrol agents are exposed to a wide range of biotic interactions. The weeds like any other plants have evolved multiple defence mechanisms, by virtue of which they either succumb or often cope up to become resistant to the multi-dimensional stress, in order to maintain their fitness.

The present study, revolved around the release of various secondary metabolites of, one of major invasive macrophyte, *Eichhornia crassipes* Mart. Solms- Laubach (Pontederiaceae) in response to the release of its biocontrol agents- *Neochetina bruchi* Hustache (Coleoptera: Curculionidae) and *Orthrogalumna terebrantis* Wallwork (Acarina: Galumnidae) and a phytopathogen *Fusarium oxysporum* Schlecht (Hypocreales:Nectriaceae), singly and in combination.

The metabolite content can be either ‘constitutive’, indicating their presence beforehand, or ‘induced’, with post- formed chemicals in response to herbivore or pathogen attack. By the virtue of nature to defend, varying amounts of several secondary metabolites (*i.e.* phenols, flavonoids, terpenoids, alkaloids, *etc.*) were recorded from the biocontrol agent attacked and non-attacked weed. Increased content of alkaloid, phenol or tannin, which *E. crassipes* produced when infested by its agents, deterred the later by providing a toxic unpleasant atmosphere, unsuitable for the pathogen/herbivore to infect/infest and flourish. Phenols, like many other secreted metabolites, are widespread and appeared to function in different capacities in various plant defence mechanisms against the used biocontrol agents. The deterrents’ property of the phenol alters the nutritional quality of the plant tissues for herbivores. Constitutive tannins content remains almost unchanged as they have antimicrobial properties, which help to hold on to the turgidity of the weed, under the effects of different agents. On the other hand, variation in the flavanoid levels directed some physiochemical changes in the weed, which impeded the entry of the phytopathogen. While few metabolites were used to dissuade the agents, some others like glycosides, attracted their feeders to lay eggs, allowing their population to flourish.

This study concentrates on the signals that enable *E. crassipes* to recognize and respond to arthropod and/ or pathogen attack and measure the effect in biochemical terms. Through this study, an overall outlook of the fitness costs of attack not only for the weed but also over the range of trophic levels has been enlightened with more scope to understand the underlying mechanisms, before the release of multiple agents. Damage by herbivores or pathogens can cause variation in plant chemical profile and metabolites, affecting the plant organic volatile and non-volatile compounds production and the nutrients profile in addition to visual cues. Therefore, understanding of micro organism–arthropod–plant interactions is critical, not only to assist in the development of new genetic varieties but also in integrated pest management programs. It instigates us for further analysis of bimolecular interaction while designing the weed biocontrol programmes in future.

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Long-term effect of conservation agriculture on weed dynamics and productivity of rice-based cropping systems

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Rice-wheat rotation is one of the largest agricultural production systems, occupying nearly 14 million ha (10.5 m ha in India, 2.2 m ha in Pakistan, 0.8 m ha in Bangladesh and 0.5 m ha in Nepal) in Indo-Gangetic Plain (IGP) of South Asia and feeds about 1.3 billion people (20% of the world population). However, present evidences indicate that the system productivity of traditional rice-wheat cropping system is plateauing and total factor productivity is declining due to fatigued natural resource base. Therefore, in recent years, the major emphasis in the rice-wheat system has been on use of resource conservation technologies (RCTs), especially zero tillage (ZT), and crop diversification. Weed infestation is a major bottleneck in ZT system. However, using ZT with crop residue retention on soil surface and crop diversification along with the proper weed management technologies, it is possible to raise the productivity of crops, and improve soil health. Altering tillage practices has a strong influence on soil weed seedbank, which may affect the relative abundance of weed species in field and efficacy of control practices. Hence, the present experiment was planned to study the long-term effect of CA practices on weed (including weed seedbank in soil) dynamics in rice-based cropping systems.

A long-term field experiment was initiated in 2009 to evaluate the impact of different crop establishment practices on yield and sustainability of rice based cropping systems in Eastern India. Results after 7th year revealed that continuous zero tillage in rice (ZTDSR) resulted in severe infestation of grassy weeds such as *Leptochloa chinensis, Digitaria sanguinalis* and *Brachiaria ramosa*. Whereas the broad-leaved weeds like *Alternanthera sessilis* and *Caesulia axillaris* were more common in conventional transplanted rice. Soil weed seed bank studies revealed that maximum number of total weed seeds/kg soil (based on seedling emergence) were observed in continuous ZT DSR - ZT wheat - ZT greengram (38.75) followed by CT rice-ZT wheat - ZT greengram (29.38), and CT rice-CT wheat (19.38). Weed seeds were maximum on 0-10 cm depth (43.44/kg soil) that 10-20 cm (15/kg soil). Irrespective of the weed species, maximum weed seeds/kg soil was present in upper surface (0-10 cm) than in the deeper layer (10-20 cm). Among different species, *Braciaria* spp, *Cyperus iria* and total grasses were maximum in ZT DSR - ZT wheat - ZT greengram, where as the total broad-leaved weeds dominated by *Trianthema portulacastrum* was higher in CT rice - ZT wheat - ZT greengram system.

Studies on bio-efficacy and phytotoxicity effect of quinchlorac in direct-seeded rice under eastern region of Uttar Pradesh

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In UP, rice is cultivated on an area of about 5.87 million hectares with the total production of 12.22 million tonnes of rice. Weeds are the most severe constraints and timely weed management is crucial for increasing the productivity under direct-seeded rice (DSR). Weeds are the main biological constraints to the production of DSR. The experiment was carried out in RBD with seven treatments *i.e.* quinchloac 35% SC (Exocet) at 350 g/ha, quinchloac 35% SC (Exocet) at 437.5 g/ha, quinchloac 35% SC (Exocet) at 525 g/ha, quinchloac 35% SC (Exocet) at 700 g/ha, bispyribac-sodium 10% SC 20 g/ha, two handweeding (weed free) and weedy check and it was replicated thrice in 2016. The net plot size was 4 x 4 m. The variety cultivated during both the year was '*Rajendra Kasturi*'. The fertilizer used were 120, 60, 40 and 25 kg/ha NPK and $ZnSO_4$ respectively. Quadrat (25 cm^2) was placed in each plot at random to determine the weed density. The maximum plant height (127.44 cm) was obtained with treatment of hand weeding which was statistically at par with bispyribac-sodium 10% SC at 20 g/ha, quinchloac 35% SC at 700 g/ha and quinchloac 35% SC at 535 g/ha and significantly superior over rest of the treatments. The highest number of tillers per meter square was recorded in hand weeding (216.98) which was significantly superior over rest of the treatments. The maximum number of grains per panicle was recorded with hand weeding (110) which was statistically at par with quinchloac 35% SC at 700 g/ ha. Similar trend was followed by grain yield. There was no phytotoxicity observed. The lowest weed dry weight was recorded with hand weeding and among chemical treatments, quinchloac 35% SC at 700 g/ha being statistically at par with bispyribac-sodium 10% SC at 20 g/ha was significantly superior over rest of the treatments. The highest weed control efficiency was recorded with hand weeding which was closely followed by quinchloac 35% SC at 700 g/ha and bispyribac-sodium 10% SC at 20 g/ha.

Weed management in rice-based croppingsystems of Andhra Pradesh

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The cultivation of high yielding crop varieties responsive to fertilizers, irrigation and new intensive cropping systems have brought to the fore front problem of weeds, which cause serious loss in crop production. The reduction in crop yield due to weeds depends upon crop and cropping system, variety, weed species and density, plant spacing, fertility and moisture status of the soil, climate as well as environmental conditions. Agriculture is diversified with 28 crops under cultivation with rice, maize, pulses, groundnut, cotton, chillies, tobacco and sugarcane as major crops in all the 13 districts of Andhra Pradesh. The cropped areas in Andhra Pradesh are divided into six agro-climatic zones *viz.*, Krishna, Godavari, North Coastal, Southern, Scarce Rainfall and High Altitude and Tribal zones based on the rainfall received, type and topography of the soil. The mean annual rainfall of the state is 852 mm, which mostly receives from south west monsoon (556 mm) and 296 mm from north east monsoon. The important rice-based cropping systems are rice-rice, rice-rice-pulse, rice-pulse, rice-maize, rice-jowar and rice-groundnut. The dominant weed flora in the rice-based cropping systems are *Echinochloa colona, Dinebra retroflexa, Panicum repens, Dactyloctenium aegyptium, Leptochloa chinensis, Leersia hexandra, Cynodon dactylon* (grasses), *Cyperus rotundus, Fimbristylis milaceae* (sedges), *Chrozophora rottleri, Grangea maderas petana, Cardanthera uliginosa, Gnaphalium polycaulon, Nasturitium indicum, Cleome chelidoni, Bergia ammannoides, Xanthium strumarium, Cardiospermum helicaba, Eclipta alba, Lippia nodiflora, Euphorbia virgatus, Digera arvensis, Trianthema portulacastrum, Commelina benghalensis, Cynotis axillaris, Eclipta alba, Phyllanthus niruri, Amaranthus viridis* (broad-leaf weeds).

Weed management became an integral part of crop production and use of herbicides gaining popularity in all the rice-based cropping systems of Andhra Pradesh due to non availability of labour in time and increased labour wages. Herbicides alone may not give the best optimum solution to all weed problems in all situations in the long run. Thus, there is every need to develop sustainable weed management strategies to address the diversified weed problems of rice-based cropping systems for effective and economical weed control. This requires the generation of knowledge on weed biology and ecology and on the consequences of changes in management and the environment on weed populations in different agro-climatic zones. Further, the improved weed management techniques should focus on shifting crop-weed competition balance in favour of rice and its component crops, by integrating possible preventive and control measures like physical/mechanical, cultural, genetical, biological methods with judicious use of herbicides in order to slow down the emergence of new weed problems like weedy rice in rice, *Vicia* in rice-fallow pulses *etc.* Weed management in some important component crops of different rice-based cropping systems, socio-economic aspects and further research on this aspect have been discussed

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Management of chocolate weed - an emerging weed in rice

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Chocolate weed or red weed (*Melochia corchorifola* L.) is a weedy tropical plant, usually seen in waste lands. In Kerala, it is a common weed in banana, sesame and rice. It usually occurs in many regions in sunny/ slightly shaded and humid areas in fields and waste places. Earlier seen only in upland areas, *M. corchorifolia* is now a common rice weed during the *Kharif* season. Knowledge of the ecological conditions for germination and the absence or presence of dormancy is a requirement to develop proper management strategies for the weed. Studies revealed that when buried at different soil depths, seeds upto 5 cm had the greatest opportunity to germinate. *M. corchorifolia* was found to exhibit dormancy and failed to germinate when sown for up to one year after maturity. Hot water treatment was found to be effective in breaking dormancy. Management of chocolate weed in dry seeded rice with various physical, cultural and chemical measures was attempted. Weeding with hand hoe at 20 and 40 days after sowing was the physical method of control while the two cultural methods tried included soil solarization for 30 days in the month of April, and mulching with paddy straw immediately after sowing. Chemical control was attempted with the pre-emergence herbicides pretilachlor and oxyfluorfen. Post-emergence herbicides tried included pyrazosulfuron-ethyl, 2, 4-D, bispyribac sodium, carfentrazone-ethyl, penoxsulam, and pretilachlor + benzsulfuron-methyl. A weedy check was also included. Rice variety '*Jyothi*' was dry sown in May 2016.

The major broad-leaved weeds present were *M. corchorifolia, Ludwigia parviflora, Eclipta alba,* and *Aeschnomene indica,* while the main sedges were species of *Cyperus* sp. The grass weeds included *Isachne miliacea, Echinochloa colona, Sacciolepis interrupta,* and *Digitaria* sp. Dry weight of weeds at 40 days after sowing was highest in the weedy check. Lowest weed dry weight was observed in oxyfluorfen treated plots. This was followed by the herbicide treatments pretilachlor + bensulfuron-methyl, 2, 4-D, carfentrazone-ethyl and bispyribac sodium. Broad-leaved weeds dominated in the field and these herbicides were effective in controlling these as well as sedges. Hand hoeing and soil solarization yielded results on a par with these herbicides. Considering chocolate weed, oxyfluorfen, 2, 4-D, pretilachlor + bensulfuron-methyl, carfentrazone-ethyl, and pretilachlor were effective in reducing the growth of the weed. Hand hoeing also yielded good control, but soil solarization was not as effective.

Highest rice grain yields were obtained in the treatments oxyfluorfen (4.15 t/ha) and carfentrazone ethyl (4.3 t/ha). This was followed by hand hoeing, which resulted in 3.66 t/ha of grain yield. Straw yield was also highest when pre-emergence application of oxyfluorfen was done. Pre-emergence application of oxyfluorfen was thus found to be the best treatment for controlling chocolate weed as well as other weeds, and for obtaining high rice yields.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Synergism and antagonism in herbicide mixtures involving cyhalofop-p-butyl

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A field experiment was conducted in *Kole* lands of Thrissur District, Kerala from September 2015 to January 2016 in rice to study the effectiveness of various herbicidal combinations as tank mix application for weed control in direct seeded wet land rice. A high yielding medium duration rice variety *Uma* was used. The treatments consisted of combinations of cyhalofop-butyl with some commonly used rice herbicides for control of broad-leaved weeds and sedges and pre-emergenes herbicides. The treatments were cyhalofop + Almix, cyhalofop + ethoxysulfuron, cyhalofop + carfentrazone, cyhalofop + pyrazosulfuron, cyhalofop + pretilachlor, cyhalofop + pendimethalin. Each treatment combination herbicides were also tried separately without mixing, as per existing recommendation, to assess the antagonism or synergism in herbicidal activity as the case may be. A broad spectrum herbicide bispyribac sodium, hand weeding, no weeding and cyhalofop-butyl alone were also included for effective comparison making a total of 16 treatments. All tank mix applications were done at 18 days after sowing (DAS) and follow up sprays at 20 DAS. Pre-emergence herbicides were sprayed six days after sowing and pyrazosulf uron at 10 DAS. Hand weeding was carried out at 20 and 40 DAS.

Major weed flora in the experimental field included grassess and broad-leaved weeds and at 30 DAS they constituted 47 and 46% of the population respectively. *Echinochloa stagnina* and *Monochoria vaginalis* were the dominant weed species. The population of sedges was very low and at 18 DAS no sedges were present. However at 30 DAS sedge population in unweeded control was 5 numbers/square meter. Among tank mix applications, a combination of cyhalofop with pyrazosulfuron recorded the least dry matter production. Both tank mix and sequential application of carfentrazone resulted in phytotoxicity to rice, but the growth parameters were not affected due to this as the crop recovered by one week after spraying. It was found that a combination spray of cyhalofop-butyl with pyrazosulfuron was very effective with a weed control efficiency of 91% at 60 DAS, which was comparable to that of bispyribac sodium probably due to herbicide synergism. A combination cyhalofop with Almix lead to poor weed control efficiency indicating some antagonistic effect. The results indicated that cyhalofop lost its herbicidal activity, while Almix retained its activity when these two herbicides are mixed. It is not advisable to mix pretilachlor or pendimethalin with cyhalofop as the combination resulted in poor WCE of 46% and 61%, respectively at 30 DAS. The most effective treatment in terms of high WCE was cyhalofop-butyl at 18 DAS with a follow up spray of Almix at 20 DAS. Except pyrazosufuron all other herbicides resulted in a weed index in the range of 13-18%.

Direct-seeded rice in North-Western India: Weed dynamics and management strategies

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Direct deeded rice (DSR) is catching the attention of farmers, researchers and policy planners as an alternate establishment method for rice in north-western India due to reduced labor costs, and savings in water and energy use. However, the field situations are favourable for emergence of weeds due to absence of continuous flooding; hence weed management is more challenging in DSR. A series of field experiments and farmer-participatory trials were undertaken in Haryana during the last decade (2006-07 to 2016-17) to understand and address some of the complex issues related to DSR, along with a survey on perception of farmers about DSR during 2012 and 2013. Initial weed dynamics studies indicated that there was a very fast shift in weed flora with change in establishment method from puddle transplanted rice (PTR) to DSR. *Echinochloa crus-galli* remained the dominant weed under PTR. Whereas, other grass weeds such as *Leptochloa chinensis, Eragrostis* spp, *Dactyloctenium aegyptium* and *Eleusine indica* which were minor weeds in PTR became major weeds in DSR. Infestation of sedges like *Cyperus rotundus* also increased under DSR. The weed emergence also continued for prolonged period, which further added to the complexity of weed management in DSR. Within DSR, there was more and early emergence of weeds under dry DSR (irrigating the field after sowing) than *vattar* (moist) sowing of DSR.

Stale seedbed technique was found effective in reducing weed infestation and controlling volunteer rice plants in DSR. Inclusion of *Sesbania,* cowpea and mung bean as green cover crops also helped in decreasing the weed infestation in the main DSR crop. Bispyribac-sodium 25 g/ha sprayed at 15-25 days after sowing (DAS) was quite effective against *Echinochloa crus-galli* and some broad-leaf weed (BLW) species in DSR. Pre-emergence application of pendimethalin 1000 g/ha or pretilachlor + safener 500 g/ha or oxadiargyl 100 g/ha could be used to effectively control other grass weeds such as *Dactyloctenium aegyptium, Leptochloa chinensis, Eragrostis* spp. and *Eleusine indica.* However, pendimethalin was the best among these herbicides, but soil moisture was crucial for its better efficacy. Tank-mix of azimsulfuron 20 g/ha, pyrazosulfuron 25 g/ha, ethoxysulfuron 18.8 g/ha or metsulfuron + chlorimuron (ready-mix) 4 g/ha with bispyribac 25 g/ha also provided effective control of BLW and sedges along with *Echinochloa* spp; however, azimsulfuron and pyrazosulfuron were better choice against sedges like *Cyperus rotundus.* Fenoxaprop (with safener) 60 g/ha was found promising post-emergence herbicide against these grasses, but its tank-mix application was antagonistic on bispyribac. Cyhalofop-butyl could also be an early post-emergence herbicide against these grasses. Farmers in Haryana have now widely adopted the use of pendimethalin 1000 g/ha followed by bispyribac 25 g/ha for broad-spectrum weed control in DSR. One hand-weeding may be given to prevent seed production by weeds that escape herbicide treatments. Survey in 2012-2013 also revealed higher infestation of grasses and sedges (98%) along with volunteer rice (10%) in DSR than PTR, which was consistent with the results of field experiments. Based on long-term field experiment during 2010-11 to 2016-17 at Karnal, productivity of *basmati* rice under DSR was found to be similar to PTR but the cost of production was lower in DSR. The DSR based rice-wheat system gave higher system productivity and net economic returns mainly due to higher wheat productivity by 0.4-0.6 t/ha.

Weed dynamics and management options under different rice establishment methods in dry season

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Rice (*Oryza sativa* L.) is most important staple food and key pillar of food security. Current issues of climate change, labour scarcity and water shortage are major drivers for the shift from conventional transplanting of rice to direct-seeding or other innovative alternatives. Floristic composition, population dynamics and growth attributes of weeds vary according to agro-climatic conditions as well as crop establishment methods. Choosing a sound weed management practice compatible to establishment method is, therefore, very much critical.

A comprehensive study was conducted in dry (*Boro*) season during 2011-12 and 2012-13 at Rice Research Station, Chinsurah, West Bengal. Three establishment methods *viz.* System of Rice Intensification (SRI), drum-seeding of sprouted seeds (DSS) and conventional transplanting of rice (CTR) were assigned in main plots, whereas eight weed management treatments comprising of pyrazosulfuron-ethyl at 25 g/ha at 5 days after sowing (DAS) / transplanting (DAT) *fb* cono weeding (CW) at 25 DAS/DAT, bispyribac-sodium at 25 g/ha (15 DAS/DAT) *fb* CW (25 DAS/DAT), azimsulfuron at 35 g/ha (15 DAS/DAT) *fb* CW (25 DAS/DAT), penoxsulam at 25 g/ha (10 DAS/DAT) *fb* CW (25 DAS/DAT), metsulfuron-ethyl + chlorimuron-ethyl at 4 g/ha (10 DAS/DAT) *fb* CW (25 DAS/DAT), one CW (25 DAS/DAT), two hand weeding (20 and 40 DAS/DAT) and weedy check were in sub-plots in a split-plot design replicated thrice. Rice variety '*Khitish*' was raised with recommended package of practices. Data were recorded on crop and weed growth at 45, 60 and 75 DAS/DAT, and grain yield at harvest. Production economics were worked out.

Irrespective of establishment methods, the crop at initial growth stage was highly infested with broad-leaved weeds, *fb* sedges and grasses. Major weeds under SRI were *Cynodon dactylon*, *Echinochloa colona*, *E. crus-galli*, *Eleusine indica* and *Leptochloa chinensis* (grasses); *Cyperus difformis*, *C. iria*, *C. rotundus* and *Fimbristylis miliacea* (sedges); and *Commelina benghalensis*, *Eclipta alba* and *Euphorbia hirta* (broad-leaved) whilst *E. crus-galli*, *C. difformis*, *F. miliacea*, *E. alba*, *Ludwigia parviflora*, *Marsilea quadrifolia* and *Monochoria vaginalis* were in common under DSS and CTR. *C. dactylon* and *E. indica* remained absent under DSS and CTR, whereas *C. rotundus* did not appear under CTR.

As of pooled data, SRI significantly registered the highest grain yield (5.67 t/ha), compared with DSS (5.32 t/ha) and CTR (5.27 t/ha), whereas the highest net return was fetched under DSS, *fb* SRI and CTR. Efficacies of weed management treatments were found significantly better under SRI (31.11 no./m^2 and 15.98 g/m^2) than DSS (35.62 no./m^2 and 17.82 g/m^2) and CTR (35.74 no./m^2 and 17.71 g/m^2) towards suppression of weed density and biomass at 45 DAS/DAT. Integrated use of bispyribac-sodium 25 g/ha (15 DAS/DAT), azimsulfuron 35 g/ha (15 DAS/DAT) or metsulfuron-methyl + chlorimuron-ethyl 4 g/ha (10 DAS/DAT) along with one CW (25 DAS/DAT) proved to be cost-effective to manage complex weed flora, exhibiting higher grain yield (5.73, 5.71 and 5.48 t/ha, respectively) and net economic return (INR 20360, 20243 and 19406/ha, respectively) under all establishment methods.

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Nutrient uptake by upland rice and associated weeds as influenced by stale seed bed and weed management methods

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A field experiment was carried out during *Kharif* 2017 at Coconut Research Station, Balaramapuram, Thiruvananthapuram, Kerala to study the effect of stale seed bed and weed management methods on density and dry weight of weeds, nutrient uptake by crop, nutrient removal by weeds and grain yield of upland rice. The experiment was laid out in randomized block design (factorial) with 16 treatment combinations and three replications. The treatments consisted of two stale seed bed methods, *viz.* stale seed bed with mechanical removal of weeds (s_1) and no stale seedbed (s_2) and eight weed management methods, penoxsulam 20 g/ha at 10-15 days after sowing *fb* hand weeding (HW) at 35-40 DAS (m_1), penoxsulam 25 g/ha at 10-15 DAS *fb* HW at 35-40 DAS (m_2), penoxsulam 30 g/ha at 10-15 DAS *fb* HW at 35-40 DAS (m_3), penoxsulam 20 g/ha at 10-15 DAS *fb* metsulfuron-methyl + chlorimuron-ethyl (MM + CE) 4 g/ha at 35-40 DAS (m_4), penoxsulam 25 g/ha at 10-15 DAS *fb* MM + CE 4 g/ha at 35-40 DAS (m_5), penoxsulam 30 g/ha at 10-15 DAS *fb* MM + CE 4 g/ha at 35-40 DAS (m_6), HW twice at 15 and 35 DAS (m_7) and weedy check (m_8).

Stale seed bed method (s_1) recorded significantly lower weed density and higher grain yield, straw yield and nutrient uptake by crop compared to no stale seed bed (s_2). Among the weed management methods, penoxsulam 20 and 30 g/ha *fb* MM + CE recorded the lowest total weed density at 60 DAS. However, these treatments were comparable with penoxsulam 20 and 25 g/ha *fb* HW indicating that either MM + CE or HW can be integrated with penoxsulam for effective control of weeds in upland rice. The herbicide treatments and hand weeding twice (HWT) treatment significantly reduced the total dry weight of weeds compared to weedy check. All the tested doses of penoxsulam 20, 25 and 30 g/ha *fb* either MM + CE or HW were very effective in reducing the total weed dry weight indicating the effectiveness of the post-emergence herbicide in reducing the weed problem in upland rice. Significantly lower nutrient removal by weeds was noticed in all the herbicide treatments compared to HWT and weedy check. Among the weed management methods, penoxsulam 25 g/ha at 10-15 DAS *fb* HW at 35-40 DAS (m_2) recorded the highest grain yield and nutrient uptake by crop and recorded comparatively lower nutrient removal by weeds. Hence, integeration of stale seedbed with application of penoxsulam 25 g/ha at 10-15 DAS *fb* HW at 35-40 DAS can be recommended for effective weed management and better availability and uptake of nutrients and higher grain yield in upland rice.

Efficacy of various herbicides combinations to control weeds in dry direct-seeded rice

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The biggest challenge in dry direct-seeded rice cultivation is to develop technologies for producing more rice with less weed problem. Best herbicide combination is one such option to minimize weed problem in dry direct-seeded rice. Hence, a field experiment was conducted at Main Research Station, Hebbal, Bengaluru during *Kharif,* 2016 and 2017 to study the effect of different herbicide combinations and weed management practices on major weed flora, yield and weed index in dry direct-seeded rice. The experiment consisted 12 treatments, *viz.* bensulfuron-methyl + pretilachlor *fb* triafamone + ethoxysulfurn (RM) (60 + 600/60 g/ha), oxadiargyl *fb* triafamone + ethoxysulfuron (RM) (100/60 g/ha), pendimetalin *fb* triafamone + ethoxysulfuron (RM) (1000/60 g/ha), pyrazosulfuron- ethyl *fb* triafamone + ethoxysulfuron (RM) (20/60 g/ha), bensulfuron-methyl + pretilachlor *fb* bispyribac sodium (60 + 600/25 g/ha), oxadiargyl *fb* bispyribac sodium (100/25 g/ha), pendimethalin* *fb* bispyribac sodium (1000/25 g/ha), pyrazosulfuron-ethyl *fb* bispyribac sodium (20/25 g/ha), pendimethalin* *fb* penoxsulam + cyhalofop-butyl (RM) (1000/135 g/ha), three mechanical weedings (20, 40, 60 DAS), hand weedings (20, 40, 60 DAS) and weedy check were tested in a Randomized Block Design with three replications. The soil type was sandy loam with a pH of 6.8, with organic carbon of 0.55 per cent. Weeds such as *Cyperus rotundus*, *Digitaria marginata*, *Ageratum conyzoides*, *Commelina benghalensis*, *Cynoadon dactylon* and *Lagascea mollis* were dominant and competitive in the dry direct-seeded rice in both the years. Among various weed management treatments, hand weeding at 20, 40 and 60 DAS recorded significantly lowest total weed density and dry weight whereas, among herbicide combinations bensulfuron-methyl + pretilachlor as pre-emergence *fb* bispyribac sodium recorded significantly lowest total weed density and dry weight and found on par with bensulfuron-methyl + pretilachlor as pre-emergence *fb* triafamone + ethoxysulfuron. Significantly, highest plant height and panicles per meter row length was observed in hand weeding at 20, 40 and 60 DAS (36.85 cm at 60 DAS and 223.08 per meter row length, respectively) and found on par with bensulfuron-methyl + pretilachlor *fb* bispyribac sodium (36.46 cm at 60 DAS and 217.60 per meter row length, respectively) and significantly higher paddy grain and straw yield was recorded in hand weeding at 20, 40 and 60 DAS (5.50 and 7.16 t/ha, respectively) and found on par with application of bensulfuron-methyl + pretilachlor as pre-emergence *fb* bispyribac sodium (5.39 and 7.22 t/ha, respectively). Whereas, higher net returns and benefit cost ratio was noticed in bensulfuron-methyl + pretilachlor as pre-emergence *fb* bispyribac sodium at 25 DAS (Rs. 59,276/ha and 2.93, respectively). Whereas, it was only (Rs. 57,042/ha and 2.63) in hand weeding plots. Results of the study revealed that pre-emergence application of bensulfuron-methyl + pretilachlor *fb* bispyribac sodium can be recommended for better control of weeds, higher productivity and economic returns in dry direct- seeded rice at Karnataka.

Integrated weed management through tank mix herbicides in transplanted rice under sub-montane zone of Maharashtra

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Rice is the staple food for millions of people in India. It will be very challenging to feed the projected population of 1.7 billion people in India by 2050. In the last five years the cost of production on different operations is increased by 33% on seed, 45% on fertilizers, 100% on labour wages, 35-40% on tillage operations making the cultivation of rice unprofitable. Weeds in rice are one of the most important biological hindrances to yield increase. Weed infestations during the crop growing season can reduce rice yields 57-61% in transplanted rice. However, heavy reliance on herbicides creates an environment favourable for weed resistance to herbicides, weed population shifts and off-site movements of herbicides. Hence, present study was carried out to evaluate the efficacy of different chemical weed control methods and its economics in transplanted rice. The field experiment was conducted at Rice Research Station of MPKV, Rahuri during 2012-2016 with the nine treatments having combination of three herbicides (*viz.* Bispiribic-sodium, 2, 4-D, metsulfuron-methyl, chlorimuron-ethyl) as alone and in combination *fb* hand weeding 45 DAT. The weedy and weed free check were taken as control plots. The experiment was laid in randomized block design. The soil was medium to deep black with the slightly acidic pH. Post-emergence application of bispyribac-sodium 10% SC at 0.020 kg/ha followed by one hand weeding 45 days after transplanting had lowest dry matter of weeds (1.72 q/ha) with higher weed control efficiency (87.74%)and lower weed index (2.83). Significantly the highest grain and straw yields of paddy (5.63 t/ha and 6.27 t/ha, respectively) were obtained in the weed free treatment. It was at par with post emergence application of bispyribac-sodium 10% SC at 0.020 kg/ha followed by one hand weeding 45 days after transplanting having grain yield (5.46 t/ha), straw yield (6.08 t/ha) and gross returns (Rs. 125740/ha).

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Integrated weed management techniques in system of rice intensification

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Weed infestation is one of the major constraints in rice grown under system of rice intensification (SRI) due to wide planting geometry and moist environment, thereby reducing rice yield up to 70%. *Echinochloa* spp., *Cynodon dactylon, Portulaca quadrifolia* and *Cyperus* spp. are the major weeds associated with SRI in Bihar. The experiment was conducted as on-farm (Nalanda and Gaya districts) and on-station at ICAR-RCER, Patna during *Kharif* season of 2015-17. Seven weed management treatments *viz.*, conoweeder thrice at 15, 25 and 35 DAT, conoweeder twice at 15 and 30 DAT, bispyribac sodium at 25 g/ha at 25 DAT + conoweeder once at 35 DAT, handweeding at 15 DAT followed by bispyribac at 25 DAT followed by handweeding at 35 DAT, conoweeder once at 15 DAT + bispyribac, unweeded check and farmers' practice were evaluated in a randomized block design with three replications. Twelve days old seedlings of hybrid rice '*Arize-6444*' were used (1 seedling/hill at a spacing of 25 x 25 cm). Seed was treated with *Trichoderma virdi* at 5 g/kg seed. Half of the recommended dose of N (50 kg/ha) through vermicompost and full dose of P_2O_5 and K_2O at 60 and 40 kg/ha, respectively were given through single super phosphate and muriate of potash before transplanting at final land preparation and remaining N (50 kg/ha) was top-dressed in 2 equal splits, half at active tillering and the rest half at panicle initiation stage. Results of on-station experiment at Patna revealed that standard practice of SRI (mechanical weeding by conoweeder at 15, 25 and 35 DAT) was the most effective in controlling weeds up to 60 DAT with the highest weed control efficiency (83.55%). The highest grain (6.25 t/ha) and straw (7.84 t/ha) yields and net returns (Rs. 60,462/ha) were also recorded under this treatment. The next best treatment was use of conoweeder twice at 15 and 30 DAT with the highest weed control efficiency (80.76%) as well as the maximum grain (5.50 t/ha) and straw (6.97 t/ha) yields and net returns (Rs. 45,512/ha). Thus, these two treatments could increase yield attributes as well as yield of rice significantly as compared to other treatments. At farmer's fields in Gaya and Nalanda districts of Bihar, the highest grain yields of rice were recorded corresponding to on-station experiments. Economic analysis of overall data (on-farm and on-station) revealed that the net returns was the highest under mechanical weeding by conoweeder at 15, 25 and 35 DAT followed by use of conoweeder twice at 15 and 30 DAT. It is concluded that for the highest productivity of rice under SRI, weeds can be effectively managed by application of conoweeder at 15, 25 and 35 DAT.

Impact of different methods of rice establishment and weed management options on crop productivity and profitability

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Direct seeding of sprouted seeds has been claimed in the recent past as an economically viable alternative to transplanting and is advantageous in areas of shortage of labour. The degree of weed competition and extent of yield losses vary with rice cultures and final choice of weed control measures will depend largely on its effectiveness and economics. A field experiment was conducted during *Kharif* 2016 and 2017 to study the impact of different methods of rice establishment and weed management options on weed control, productivity and profitability. The experiment was laid out in split plot design with three replications. The treatments consisted of three establishment methods of rice *viz.,* transplanted rice, wet-direct seeded rice and aerobic rice and five levels of weed management practices, *viz.* bispyribac sodium 25 g/ha as PE *fb* fenoxaprop-p-ethyl 62 g/ha + 2, 4-D 0.5 kg/ha, pendimethalin + penoxsulam 25 g + 600 g/ha PE at 4-7 DAS/DAT, pretilachlor 0.75 kg/ ha as PE *fb* hand weeding at 40 DAT/DAS, Hand weeding 20 and 40 DAT/DAS and unweeded control.

The weed spectrum of the experimental field consisted of *Cynodon dactylon, Dinebra retroflexa, Echinochloa crus-galli* and *Paspalum distichum* among grasses; *Cyperus difformis, Cyperus iria* and *Scirpus* spp. among sedges and *Eclipta alba, Ammania baccifera, Trianthema portulacastrum, Euphorbia geniculata, Euphorbia hirta* and *Amaranthus viridis* among BLWs. Transplanted rice recorded lowest weed density, weed biomass and higher weed control efficiency at all the stages of crop growth. Among weed management practices, application of pretilachlor as PE *fb* hand weeding 40 DAS/T recorded the lowest weed density, biomass and higher weed control efficiency. Growth parameters and yield were significantly higher in direct seeded rice and on par with transplanted rice. Pretilachlor as PE *fb* hand weeding at 40 DAS/ T recorded higher growth and yield attributes over rest of the treatments. Direct seeded rice and transplanted rice recorded highest grain and straw yield. Pretilachlor as PE *fb* hand weeding at 40 DAS/T, though it was at par with hand weeding twice at 20 and 40 DAS/T produced significantly more grain yield, straw yield and harvest index as compared to other treatments. The maximum net return was recorded with direct seeded rice under puddled condition with application of pretilachlor as PE *fb* HW at 40 DAS/T over rest of the treatments. The benefit:cost ratio was found highest under direct seeded rice and transplanted rice with the application of pendimethalin + penoxsulam as PE at 4-7 DAS/T over rest of the treatments. The highest net energy output, total energy use efficiency and total energy productivity was observed with direct seeded rice and was on par with transplanting. Pretilachlor as PE *fb* HW at 40 DAS/T found to have highest net energy output, total energy use efficiency and total energy productivity.

Weed dynamics and crop productivity in rice-wheat-greengram cropping system under conservation agriculture in vertisol

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Worldwide, Conservation Agriculture (CA) has received attention to address the issues of conventional tillage (CT), it includes soil degradation, weed pressure and crop yield reductions. Conservation agriculture comprising as a system based minimum soil disturbance, permanent soil cover through crop residue retention and crop rotations/diversification is widely promoted for minimizing soil degradation and enhancing crop productivity. Apart from several advantages, weeds are the major biological constraint in CA, posing a great challenge towards its adoption. Reduction in tillage intensity or frequency may significantly influence the weed emergence and infestation. The composition of weed species and their relative time of emergence differ between conservation agriculture systems (CAs) and soil inverting conventional tillage systems (CTs). Weeds need to be controlled at right time *i.e.* critical period of crop weed competition, to minimize the yield losses. Thus, long term effect of tillage and weed management practices on weed dynamics and crop productivity in rice-wheat-greengram cropping system under conservation agriculture in vertisol was evaluated at ICAR-Directorate of Weed Research, Jabalpur (MP) with an altitude of 388 m above sea level. The study was executed in split-plot design having five tillage *viz.* direct seeded rice (DSR) conventional tillage (CT) + sesbania (S)-zero tillage (ZT)-ZT, DSR CT + previous season crop residues (R) + S-CT + R-ZT + R, DSR ZT + S-ZT-ZT, DSR ZT + R + S-ZT + R-ZT + R and puddled transplanted rice (TPR)-CT-CT in main plots and three weed management practices *viz.* continuous weedy, continuous bispyribac sodium 25 g/ha- clodinafop + sulfosulfuron (60 + 25 g/ha) - pendimethalin followed by (*fb*) imazethapyr (700 *fb* 100 g/ha) respectively and herbicide rotation- clodinafop + 2,4 D (60 + 500 g/ha)-pendimethalin (700 g/ha) in sub plots. The treatment was replicated thrice. The test varieties used were MTU 1010, GW-273 and samrat, respectively.

Tillage and weed management significantly (p=0.05) influenced the weed dynamics and crop yield in rice-wheat-greengram cropping system. In rice, at 60 days after sowing (DAS), maximum weed density and weed dry weight recorded with DSR-ZT + S (37.4 no./m^2 and 40.8 g/m^2, respectively) followed by DSR-CT + S. The lowest weed parameters were obtained with TPR (11.8 no./m^2 and 15.1 g/m^2, respectively). The highest weed control efficiency was recorded in TPR (82.9%) and grain yield (3.59 t/ha) followed by DSR-ZT + R + S, whereas the lowest with DSR-ZT + S.

Among weed management practices, herbicide rotation has the lowest weed density and dry weight (3.4 no./m^2 and 5.07 g/m^2, respectively) followed by continuous use of bispyribac at 25 g/ha. The highest values of weeds were recorded with weedy check (75.87 no./m^2 and 82.53 g/m^2, respectively). Lower weed dry biomass in herbicide rotation helped to achieve better weed control efficiency (95.3%) and grain yield (5.93 t/ha) followed by bispyribac sodium over weedy check.

In wheat, the weed density was recorded lower in TPR-CT (33.4 no./m^2) and DSR ZT + R + S-ZTR-ZTR at 60 DAS, whereas, weed dry weight recorded lowest with DSR ZT + R + S-ZTR-ZTR (18.4 g/m^2) followed by TPR-CT. Lower weed density and dry weight under DSR ZT + R + S-ZTR-ZTR significantly improved weed control efficiency (63.7%) and grain yield (4.13 t/ha) followed by TPR-CT. The lower weed control efficiency obtained with DSR CT + S-CT-ZT. The highest weed density and dry biomass was recorded with DSR CT + S-CT-ZT. Among weed management practices, rotational use of herbicide has lowest weed density and dry weight (12.0 no./m^2 and 6.6 g/m^2, respectively) followed by clodinafop + sulfosulfuron, whereas the highest values were measured in weedy check. Herbicide rotation significantly controlled the wide range of weed flora resulted highest weed control efficiency (87%) and grain yield (4.63 t/ha) followed by clodinafop + sulfosulfuron over weedy check.

Long-term effects of tillage systems and weed control on weed dynamics, crops productivity and soil health in a maize-wheat production system

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The adoption of zero tillage (ZT) and conservation agriculture (CA) has expanded to cover about 1.5 million hectares in India. The major CA based technologies being adopted is zero-till wheat in the rice-wheat system of the Indo-Gangetic plains. In other crops and cropping systems, the conventional agriculture based crop management systems are gradually undergoing a paradigm shift from intensive tillage to reduced/zero-tillage operations. Maize-wheat is the third most important cropping system, after rice-wheat and rice-rice, in India. The area under ZT is on the increase in wheat while in maize is still in early stage of adoption. The planting of both crops using ZT is being promoted for conserving natural resources and sustaining productivity. The switch from conventional tillage to no-tillage cropping systems generally creates a shift in weed species. In ZT systems, weed seeds remain on the soil surface rather than being buried; and soil moisture and temperature are influenced by tillage system, potentially affecting weed and crop germination conditions. However, there is a general perception that no-till farming systems require an increased amount of herbicides, as mechanical weed control and tillage are missing from these systems, which may leave residues toxic to succeeding crops or non-targets organisms and ultimately can cause hazard to health and environment.

The long-term effects of tillage and weed control on weed dynamics, crops productivity and soil health in a maize-wheat cropping system were invetigated for 5 cropping years at Ludhiana, India. Four tillage systems (ZT-ZT; ZT- conventional tillage (CT); CT - ZT ; CT- CT) were allotted to maize-wheat system in the main-plots, and three weed control treatments (2 hand weeding; recommended herbicide (atrazine 1.0 kg/ha in maize; clodinafop 60 g/ha in wheat); unweeded control) to sub plots in a split-plot design with three replications. In maize, continuous CT favoured *Cyperus rotundus* and *Commelina benghalensis*, and alternate tillage *Digitaria ciliaris*. In wheat, ZT reduced *Phalaris minor*, irrespective of tillage system adopted in maize; alternate tillage reduced broad-leaf weeds. The tillage systems recorded differential effects on soil weed seed bank of grass and broad-leaf weeds. Averaged over 5 years, alternate tillage gave maize grain yield similar to continuous CT while continuous ZT reduced maize grain yield; in wheat, alternate tillage recorded significantly higher grain yield than continuous ZT or CT. The recommended herbicides provided effective control of weeds in maize for first 3 years, and in wheat for 5 years. Averaged over 5 cropping seasons, herbicides application increased maize grain yield by 57% and wheat yield by 45% as compared to unsprayed control; maize grain yield under herbicide and hand weeding treatments were similar, and in wheat the herbicide recorded 12% higher yield. In general, the ZT recorded higher microbial biomass than CT; herbicides use reduced the microbial populations however the effects were transient. The harvest time residues of atrazine and clodinafop in soil and in crop produce under different tillage systems were below detectable limits.

Post-emergent herbicidal weed management in maize

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Maize is one of the most important cereal crops in the world agricultural economy both as food for man and feed for animals and is a miracle crop. It is a heavy feeder of both nutrients and soil moisture due to its high productivity. Maize, being a rainy season and widely spaced crop, gets infested with a variety of weeds and subjected to heavy weed competition which often inflicts huge losses ranging from 28 to 60%. Lower yields of maize under Indian conditions may be attributed to a number of factors, among them weeds rank themselves as the premier enemy. Control of weeds from the fields of maize is, therefore, very essential for obtaining good crop harvest as weed control practices in maize result in 40 to 76% higher yields than weed check. Weeds can be controlled by cultural, mechanical and chemical measures. No doubt cultural and mechanical methods are still useful tools but are laborious, time consuming and getting expensive. Moreover, the labour problem is becoming acute day by day and it will not be possible to follow traditional cultural and mechanical weed control practices under such situations. Therefore, herbicidal options are economically most suitable for weed control. Currently, atrazine, pendimethalin, alachlor herbicides are available as pre-emergence application for weed control in maize. Usage of pre-emergence herbicides assumes greater importance in the view of their effectiveness during initial stages. Sometimes, pre-emergence herbicides are not effective against some hardy weeds, both grassy and non-grassy as well as the sedges. Also, sometimes farmer misses the application of pre-emergent herbicides and also due to the scarcity of labour at that time, the only economical option is use of post-emergent herbicides for the control weeds emerging during later stages. Therefore, it is necessary to develope cheaper post-emergent herbicides for effective control of weeds.

Use of post-emergent herbicides would make the weed control more acceptable to farmers in getting higher yields. However, only few post-emergent herbicidal options are available for weed management in maize. Tembotrione and topramezone are new herbicides for post-emergence weed control of broad-leaf and grass weeds in maize. Post-emergence application of tembotrione 120 g/ha and topramezone 20-25 g/ha were found most effective to control the grassy as well as non-grassy weeds with 85-91% weed control efficiency. These new post-emergent herbicides are reported to remain active in the soil throughout the growing season, offering control of grass and broadleaf weeds until corn canopy closure, but do not limit the crop rotation opportunities in succeeding crops in the following next season. Managing weeds through pre-emergence and post-emergence herbicides could be an ideal means for controlling the weeds in view of their economics and effectiveness in maize.

Management of herbicide resistant grassy weeds in wheat

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Wheat is a major staple food crop after rice of the world and for global food security it is necessary to have its assured production and productivity. However, weed infestation is one of the main constraints limiting its production and productivity. Wheat crop is infested with both grassy and broad-leaved weeds but the management of grassy weeds is a major challenge. Further the evolution of herbicide resistance in these weeds has made their management difficult. In India, the populations of three grassy weeds namely Littleseed canarygrass (*Phalaris minor* Retz.); wild oat (*Avena ludoviciana*) and Rabbitfoot grass (*Polypogon monspeliensis* (Linn) Desf.) have evolved herbicide resistance. *P. minor* has evolved multiple herbicide resistance to three modes of action (Photosynthesis at photosystem II site A, ACCase and ALS inhibitor). Some of the resistant (R) populations exhibited GR_{50} values for clodinafop and sulfosulfuron> 20 times greater than that of the most S (susceptible) population. Whereas, wild oat has evolved resistance against ACCase and ALS inhibitor herbicides. *Polypogon monspeliensis* has also evolved resistance against ALS inhibitor herbicides (sulfosulfuron, mesosulfuron and pyroxsulam). The evolution of herbicide resistance in multiple grassy weeds is a major threat to wheat production in India. Management strategies must be developed to prevent selection and spread of herbicide resistant populations. Many farmers in northern India having infestation of multiple herbicide resistant populations are facing significant wheat yield reductions in the absence of effective alternative herbicides. One important aspect for resistance management is early detection of herbicide resistance and to identify the effective alternative herbicides as alternative herbicides are central in herbicide resistance management.

The *P. minor* populations resistant to three modes of action (Photosynthesis at photosystem II site A, ACCase and ALS inhibitor) were sensitive to pendimethalin, flumioxazine, flufenacet, pyroxasulfone and metribuzin. Pyroxasulfone and flufenacet were also found effective for control of herbicide resistant *P. monspeliensis* and wild oat. Presently no safer post emergence options are available for wheat growers having the infestation of multiple herbicide resistant *P. minor* and some farmers are using metribuzin for its control. Its phytotoxicity varies depending on its dose, time and method of application as well as wheat cultivar. Flumioxazin applied as pre-emergence also has some phyto initially but had no adverse effect on yield. By adopting some of the agronomic practices like slightly deeper sowing, increased seed rate and tolerant cultivars herbicide injury can be reduced. However, for long term effective herbicide resistance management, alternative herbicides should be integrated with non-chemical methods consisting of crop rotation, adjustment in sowing time and method, competitive cultivar, higher seed rate, closer spacing and straw mulching. The adoption of these integrated weed management practices will help in minimizing the impact of herbicide resistant weeds on wheat production and farmers income.

Day time effect on efficacy of mesosulfuron-methyl against weeds in irrigated late sown wheat

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The field experiment entitled "Day time effect on efficacy of mesosulfuron-methyl against weeds in irrigated late sown wheat" was conducted at Research Farm, Department of Agronomy, JNKVV, Jabalpur during two *Rabi* season of 2014-15 and 2016-17. Five weed control treatments, comprising of three doses of mesosulfuron-methyl (10.0, 11.5 and 12.0 g/ha) including one hand weeding and weedy check as main plot treatments and were superimposed with three day times of herbicide application (8 a.m., 12 p.m. and 6 p.m.) as sub plot treatments and laid out in split plot design with four replications. Wheat variety *GW 273* was sown in the experimental field with recommended package of practices. The mesosulfuron-methyl was sprayed as post-emergence using a spray volume of 500 L/ha with a knapsack sprayer fitted with flat fan nozzle. Crop was irrigated uniformly under all plots. There was pre-dominance of dicot weeds (56.58 and 70.44%) as compared to monocot weeds (43.42 and 29.56%) in the experimental field during both year *i.e.* 2014-15 and 2015-16, respectively. Among the dicots, *Anagallis arvensis* was more rampant constituting 37.37 and 25.40% relative density followed by *Medicago denticulate* (14.20 and 36.31%), whereas *Phalaris minor* was dominant among the monocots (21.92 and 17.26%) followed by *Cynodon dactylon* (14.30 and 5.56%). Weedy check plots receiving no weed control had higher density and dry weight of weeds. However, identical reduction in density and dry weight of weeds was observed when weeds were controlled either chemically or mechanically. Application of mesosulfuron-methyl from 11.5 to 12.0 g/ha during noon hours was found more effective against all the weeds in wheat except *Alternanthera philoxeroides* which was controlled when mesosulfuron-methyl applied during evening time at the foresaid rates. The inferior values of crop growth parameters (number of tillers, crop biomass, leaf area index, crop growth rate and relative growth rate) and yield attributing characters (effective tillers, ear head length, number of grains per ear head and test weight) were recorded in weedy check plots which resulted in lower grain as well as straw yields. But, the values of above crop growth parameters and yield attributing characters except test weight were increased identically when weed control measures were adopted. The plots receiving mesosulfuron-methyl at 11.5 g/ha during noon time registered higher values of growth parameters (crop biomass, leaf area index, crop growth rate and relative growth rate), yield attributing traits (ear head length, number of grains per ear head) including yield and found more remunerative as it received higher values of NMR (Rs. 67901/ha) and B:C ratio (2.26) during both the years 2014-15 and 2015-16, respectively, as compared to other treatments.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Conservation agricultural practices: A weed management tool to enhance the productivity of irrigated maize – sunflower cropping system

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Sustainable crop production is necessary to ensure food security and environmental safety. Conservation agriculture (CA) is gaining popularity around the world due to its sustainable approaches such as permanent soil cover, minimal soil disturbance, planned crop rotations and integrated weed management. Weed control is the biggest challenge to CA adoption. Weed ecology and management is different in conservation agriculture than in conventional agriculture. Weed management can become a limiting factor in crop production when tillage is decreased. Changes in tillage methods can affect weed population dynamics, weed seed distribution and abundance in soil seed bank. Tillage system and crop rotation have significant long-term effects on soil productivity and quality such as soil carbon and other soil physical, biological and chemical properties. The conservation tillage methods combined with effective weed control method is to be identified for higher productivity of any cropping system. Conservation agriculture practices are the best tool for effective weed control as well as to improve the productivity of the cropping system. Field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore during *Kharif 2016* to *Rabi 2017* to study the weed seed and weed population dynamics and crop productivity in maize – sunflower cropping system as influenced by tillage and weed management methods. The experiment was laid out in split plot design with four replications. Main plot treatments consisted of five-tillage methods, *viz.* conventional tillage – conventional tillage, conventional tillage - zero tillage, zero tillage + residue – zero tillage, zero tillage – zero tillage + residue and zero tillage + residue – zero tillage + residue. Three weed management methods *viz.*, PE herbicides (Atrazine 0.5 kg/ha followed by 2,4 D at 0.75 kg/ha for maize and pendimethalin 1.0 kg/ha for sunflower) followed by herbicides with hand weeding on 40 DAS and unweeded check for both the crops consisted the subplot treatments. Two years of results revealed that in maize – sunflower cropping system of conservation agriculture, significantly higher grain yield and economics were recorded in zero tillage followed by zero tillage with crop residue and in PE pendimethalin at 1.0 kg/ha + HW on 45 DAS in sunflower crop. Whereas, in maize, conventional tillage followed by conventional tillage and PE atrazine at 0.5 kg/ha followed by hand weeding on 45 days after sowing recorded higher productivity as well as high income in maize crop. The total bacteria, fungi, actino bacteria and phosphor bacteria and soil enzymes *viz.*, alkaline phosphatase and dehydrogenase were decreased up to 5 days after application of herbicides. After 15 days, the population and enzymes activities were increased double the time compared with control in both sunflower and maize crop. Soil organic carbon and nutrients status at the harvest of both the crops were not influenced significantly by the conservation agricultural practices.

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Effect of herbicides combination for control of complex weed flora in wheat

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Wheat is an important crop worldwide and in India, it is the second most important staple food after rice. In Bihar, wheat is major *Rabi* crop and grown after harvesting of medium duration rice and long duration varieties of rice. To study the bio-efficacy of different herbicides against complex weed flora, a field experiment was laid out during winter seasons of 2014-15 and 2015-16 at Research Farm of Bihar Agricultural University, Sabour and best treatment was demonstrated on 50 farmers field in adopted village of farmers first project (Birnoudh) Bhagalpur in winter season of 2016-17 under conventional tillage and zero till condition. The soil of experimental field was sandy loam in texture, medium organic carbon, low available nitrogen and medium available phosphorus and potassium contents with slightly alkaline pH (8.0). The experiment was conducted in randomized block design with three replications with HD 2967 variety of wheat.

The major weed flora in experimental field were *Chenopodium album*, *Rumex dentatus, Medicago denticulata, Anagallis arvensis, Coronopus didymus* and *Fumaria parviflora. Polypogon monosplensis* and *Phalaris minor* were dominant grassy weeds. Maximum grain yield of wheat (4.12 t/ha) was also recorded with application of pinoxaden 0.06 kg/ha + metsulfuron (Premix) 0.004 kg/ha as PoE followed by clodinafop 0.06 kg/ha + metsulfuron (Premix) (Vesta) 0.004 kg/ha as PoE (Table 1). However, adoption of two hand weeding was recorded maximum grain yield of wheat (4.35 t/ha). Due to higher cost involved in two hand weeding treatments it was not economical. Maximum B:C ratio of 3.00 was obtained with pinoxaden 0.06 kg/ha + metsulfuron (Premix) 0.004 kg/ha. Yadav *et al.* (2016) also reported similar findings. At farmers field, the maximum profitability was recorded with the application of clodinafop 0.06 kg/ha + metsulfuron (Premix) (Vesta) 0.004 kg/ha under zero till condition due to controlling of complex weed flora. At all farmers fields, the treatment containing clodinafop at 0.06 kg/ha + metsulfuron (Premix) (Vesta) 0.004 kg/ha perform better as compared to single herbicide in conventional as well as in zero till condition. However, zero till wheat was superior as compared to conventional in terms of lower weed population and higher yield.

Effect of different wheat establishment methods and weed management practices on the major weeds and wheat

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Weeds account for about one third of total losses caused by various biotic stresses (Gopinath and Mina 2009). Yield reduction to the tune of 15 to 50% or sometime more depending upon the weed density and weed flora also reported (Jat *et al.* 2003). Wheat fields in Northern India are massively infested with wide range of grassy and non grassy weeds and to deal with the problems of weed infestation, different tillage practices tested in different climatic situations. But, alteration in tillage leads to change in weed flora. Use of herbicides can be effectively integrated with different planting patterns like zero tillage, strip till drill, roto till seed drill *etc.* sowing in standing stubbles, and zero till sowing with complete or partial burning of stubbles to allow the competition in favour of wheat. The actions of herbicides on weeds have been tested under conventional method of wheat sowing but new techniques of establishment of wheat revealed different types of weed flora with different density of weeds and their management practices are also different to the conventional system.

With this view, a field experiment was conducted during the *Rabi* season of 2013-14 at N. E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, India to find out the effect of different wheat establishment methods and weed management practices on the major weeds and wheat. Three establishment methods (Zero tilled wheat (ZTW), conventional tilled wheat (CTW) and roto till drilled wheat (RTW)) in main plots and four weed management practices (weedy, two hand weeding at 30 and 60 DAS, clodinafop-propargyl at 60 g/ha and ready mix of clodinafop-propargyl + MSM at 64 g/ha) in sub plots were studied in a split plot design (SPD) with three replication.

Density of *Coronopus didymus* was highest under RTW which was at par with ZTW and significantly higher than CTW at 60 and 90 DAS. *Polygonum plebejum* density was recorded highest under RTW followed by CTW and ZTW at 60, 90 DAS and at maturity stage. CTW recorded highest density of *Medicago denticulata* followed by ZTW and RTW at 90 DAS and maturity. Dry matter of *Coronopus didymus* was highest under ZTW followed by RTW and CTW at 60 DAS. *Polygonum plebejum* dry matter production was recorded highest under RTW followed by CTW and ZTW at 60, 90 DAS and maturity stage. Dry matter of *Medicago denticulata* was recorded maximum under ZTW and CTW at 60 DAS. Grain and biological yield did not differ significantly owing to various establishment methods of wheat. The highest grain and biological yield was obtained in the plots treated with clodinafop-propargyl at 60 g/ha which was at par with ready mix of clodinafop-propargyl + MSM at 64 g/ha and two hand weedings. Grain and biological yield loss under RTW, CTW and ZTW due to weeds was 75.9% and 30.8%, 22.3% and 11.5% and 18.3% and 14.3%, respectively

Effect of herbigation on weed dry matter and yield of kharif maize

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Maize (*Zea mays* L.) is the second most important cereal crop in the world and is known as queen of cereals because of having highest genetic yield potential. In India, it is the third most important food crop after rice and wheat in terms of its area, coverage and contribution to total food grains production. It is grown in nearly 9.26 m ha with average productivity of about 2.57 t/ha. Amongst various production factors, weed management plays major role in increasing productivity of maize. A number of weed species compete with maize and reported to reduce yield as much as 65% with delay in weed control. Farmers usually use soil applied pre emergence herbicide for weed control in maize field through knapsack sprayer. Herbigation is an application of herbicide through irrigation water can be effectively done through drip irrigation which is advanced method of precise application of water most efficiently at the required rate, at right time, at the active root zone of the crop. Field experiments were conducted for two *Kharif* seasons (2015 and 2016) to evaluate the effects of herbigation in comparison to conventional method on emergence of weeds under irrigated condition in maize. Application of herbicides through drip and conventional spraying were studied for pre-emergence application of atrazine 1.0 kg/ha, metribuzin 0.25 kg/ha and pendimethalin 1.0 kg/ha followed by hand weeding at 30 days after sowing (DAS) in combination with dripper discharge rates of 0.6, 1.0 and 2.0 LPH (litres per hour). The experiment was laid out in randomized black design (Factorial) with three replications. The crop '*DHM 117*' was supplied with 150:60:40 kg/ha of $N:P_2O_5:K_2O$. The results of herbigation studies with exiting drip irrigation system indicated that conventional/traditional method of pre-emergence application (2-3 DAS) of herbicides by knapsack sprayer with flat fan nozzle found better weed control and improving the yield of maize than herbigation with venturi of drip irrigation system. The predominant weed flora observed in the experimental field in association with the maize was grasses like *Cynadon dactylon* and *Dactyloctenium aegyptium; Convolvulus arvensis*, *Commelina benghalensis*, *Celosia argentia*, *Parthenium hysterophorus Amaranthus viridis* and *Portulaca oleracea* among broad-leaved weeds and *Cyperus rotundus in* sedges. The mean maize yield was significantly higher with traditional spraying (6.37 t/ha) than herbigation treatments with dripper discharge rates of 0.6, 1.0 and 2.0 LPH. Among herbicides, atrazine followed by pendimethalin registered significantly more yield of maize than metribuzin and there was no significant difference in weed density and dry matter among the herbicides at 30 DAS and harvest, though the atrazine recorded significantly lower weed density at 60 DAS.

Weed abundance and soil weed seed bank responses to varied tillage practices in green manure-maize-pulse cropping system

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Conservation agriculture has emerged as an effective strategy to enhance sustainable agriculture worldwide. In conservation agriculture, the soil surface residues influence soil temperature and moisture which may affect weed seed germination and emergence patterns. Conservation tillage suggests upkeep of plant residues on the soil surface and maintains soil structure by eliminating tillage for seed bed preparation and weed control. Incorporated crop residues inhibit weeds, but not crop establishment through seed size-dependent effects on germination and emergence.

The field experiments were conducted at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai during the period 2016-2018. The experimental field was located in the southern zone of Tamil Nadu at 11^0 29'N latitude and 77^0 08'E longitude with an altitude of 147 m above mean sea level. The soil of the experimental field was red sandy clay loam in texture belonging to *Madukkur* series. The experiments were laid out in a split-split plot and completely randomized block design under field and pot culture experiments respectively, with three replication. Predominant weed species noticed in the field included grasses like *Chloris barbata, Cynodon dactylon, Dactyloctenium aegyptium* and *Echinochola crusgalli; Cyperus rotundus* under sedges and broad-leaved weeds like *Acalypha indica, Boerhavia diffusa, Commelina benghalensis, Cleome viscosa, Convolvulus arvensis, Eclipta alba, Euphorbia hirta, Portulaca oleracea, Phyllanthus niruri* and *Trianthema portulacastrum.* Under both experiments, the results revealed that compared to other treatments including conventional practices, minimum tillage with pre-emergence herbicide followed by one hand weeding + 75% NPK + vermicompost + bio-fertilizer significantly recorded lesser weed density, higher weed control efficiency, lesser weed seeds in top soil (0-15cm), productivity and increased economic return in maize. Similarly in black gram, zero tillage + crop residue mulch + 75% NPK + vermicompost + bio-fertilizer achieved higher weed control efficiency and maximized the economic return along with effectively suppressing the weed seeds in top soil (0-15cm) compared to farmers' practice. Hence, it can be concluded from the present investigation that, conservation tillage (minimum/zero tillage) with pre-emergence herbicide application in maize followed by crop residue mulch in black gram, with 75% NPK + vermicompost + bio-fertilizer can be recommended to farmers to manage weeds and their seed banks under conservation agriculture system. Reducing the use of inorganic nitrogen in crop production by cultivating green manure and pulse crop helps to reduce the weed emergence, cost of input and limit the emission of NO_2 (greenhouse gas) along with restoring soil health as well as combating climate change: a threat to global agriculture.

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Conservation agriculture practices for efficient weed management

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Weeds are considered to be most potential pest causing adverse effect on agricultural productivity and quality. Excessive tillage, use of poor quality seed, weed contaminated seeds, weed shift, monoculture, non-availability of human resource for weeding, inappropriate selection and application of herbicides are key concerns for weed management in current agricultural production systems. Major problem of weeds associated with the CA based production system is due to less expertise/management skill in implementation of CA practices. Optimum crop stand is an effective tool to minimize weed infestation. Alterations in the planting pattern (planting geometry) is a cost effective technique that brings desired change in the crop canopy structure and micro-climate, to enhance crop competitiveness against weeds resulting better weed suppression. Rational crop rotation is helpful in changing the cycle of the weed which ultimately reduces the weed infestation.

Research has shown that zero tillage (ZT) combined with retention of crop residue is a potential tool for effective weed management in rice–wheat (RW) cropping system in IGP. CA based practices *i.e.* permanent no-till residue managed beds and double no-till (ZT direct seeded rice- ZT wheat) reduced weed infestation in rice-based cropping systems due to less weed seed bank disturbance in soil and proper cover of soil by the residue. ZT DSR with anchored residue was found to be most effective in minimizing weed density, dry weight and nutrient depletion by weeds. Residue retention with *Trichoderma* application was proved more effective over the residue removal in minimizing the weed density and total dry weight in ZT wheat. Although ZT alone without residue provided advantages in terms of weed suppression and yield increase in wheat but when ZT is combined with residue retention, advantage of weed suppression and yield increase are much higher. Sulfusulfuron + metsulfuron was very effective in controlling weeds in wheat. ZT rice–ZT wheat recorded higher growth, yield attributes and yield of rice-wheat system due to higher weed control efficiency and better crop establishment over conventional tilled (CT) rice–CT wheat. Application of bispyribac 25 g/ha + azimsulfuron 35 g/ha at 15-20 DAS/DAT in rice and clodinofop 60 g/ha + carfentrazone 20 g/ha at 30-35 DAS in wheat under ZT Rice - ZT Wheat system provided efficient weed management, higher yield, system productivity and system profitability in rice-wheat (RW) cropping system.

Diversification of the RW system by growing a short-duration vegetable crop (pea or potato) followed by late sown wheat also improved weed control without any increase in herbicide use, such type of practices are successfully adopted for effective weed management. Modification and interventions in tillage system, planting systems, and other management strategies can alter the soil environment and lead to a major change in weed flora. Options such as stale seed bed practice, appropriate crop establishment with CA based practices, use of cover crops and crop residues, crop rotations and crop diversification with sensible use of pre- and post-emergence herbicides should be integrated for efficient weed management

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Weeds of maize + rajmash crop system under real farm conditions of semi-temperate zone of Rajouri (Jammu and Kashmir)

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Maize + rajmash mixed cropping is a common farming practice in the hilly areas of temperate zone in Jammu & Kashmir. Maize is the staple food of the inhabitants of this area and Rajmash is considered red gold because it is a cash crop and sold at premium prices in the market. This cropping system is viable option for farmers as maize plants serve as natural supports for Rajmash plants with vines as long as three meters mutual supportive. The maize + rajmash crop mix is infested by the common *Kharif* season weeds prevalent in the region, which cause substantial loss to the yield of both the crops. The *Kharif* season in the region receives good amount of rainfall because which weed flora becomes predominant in the early stages of crop growth and suppress Rajmash as well as Maize. Thus keeping this problem in view, the weed flora associated with Maize + Rajmash cropping system in the semi temperate zone of Rajouri District of Jammu and Kashmir was surveyed in the *Kharif* season. The study was based on extensive and intensive field surveys made during different months of *Kharif* season. Two patches of one square meter each were randomly taken in the selected sites to identify the weed flora, and to take weed count. Five important villages of Budhal block were selected where Maize + Rajmash was a predominant cropping system to study the major weed flora of system and its management by the farmers under real farm condition at three sites in each village. The study revealed that farmers method of weed control in this system was only mechanical (two hoeing) one at 5-6 leaves of stage Maize and other at knee height with earthing up. No herbicide was used by the farmers in this system. A total of 48 weed species belonging to 4 monocot and 17 dicot families were reported from the study area. Out of these 21 families, the monocot Poaceae family shows predominance having 9 weed species followed by families Asteraceae and Amaranthaceae each having 5 weed species. The crop was heavily infested with weeds such as *Echinochloa crusgalli*, *Acrachne racemosa*, *Setaria viridis*, *Eleusine indica* L., *Sorghum halepense*, *Digera arvensis*, *Commelina benghalensis*, *Amaranthus viridis*, *Erigeron canadensis* and the most notorious *Ipomoea nil* and *Ipomoea purpurea* except *Ipomoea* all these weeds are used as green forage by farmers over the years during monsoon season. These weeds intervene around the Maize as well as Rajmash plants and check their growth. In mixed cropping of Maize + Rajmash, *Ipomoea* posed the serious threat to this system the twinning stem of *Ipomoea* crawl around the Maize and Rajmash plant and cover their canopy when the weight increases resulted in logging which ultimate leads to yield reduction. The present study may be helpful in identification of common weeds of *Kharif* crops. It may be useful for taxonomists, agriculturists and scientists involved in the management of weeds. Further research work is needed in the fields of weed control, weed biology and weed utilization as the component of integrated weed management.

Effect of integrated weed and nutrient management practices on growth, nutrient uptake and soil health of hybrid maize production system at alluvial soil of India

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Maize is the third important cereal crop after wheat and rice in the world. It is predominantly a rainy season crop but during past few years winter maize is gaining popularity in India. Increasing productivity with decrease in production cost for the benefit of the farming community as a whole and maintenance of soil health are newly emerging challenges for the agricultural scientists. In order to meet these challenges, there is an urgent need to develop agro-techniques related with use of right nutrient source, at the right rate, at the right time, and in the right place. On the other hand, weed is one of the most important factors that affect crop growth and yield. Yield losses in maize as high as 51 to 100% have been reported due to weed competition (Imoloame and Omolaiye 2017). The dose and source of nutrients especially nitrogen influence the weed community structure and a bit substitution of chemical source of nitrogen with organic one ultimately helps in design-effective weed management programme in crop sequence. The overall objective of the present study was to formulate a sustainable maize production system through integrated weed and nutrient management practices in alluvial plains of West Bengal. The experiment was laid out in factorial RCBD with 15 treatment combinations, replicated thrice during winter season of 2014-15 and 2015-16 in a farmer's field situated at Uttar Chandamari village, Muratipur, Nadia, and West Bengal, India, under the New Alluvial Zone. The first factor was nutrient management practices having five levels [NM_1: 100% RD_{NPK}; NM_2: 100% RD_{PK}+ 75% RD_N + 25% N vermicompost (VC); NM_3: 100% RD_{PK}+ 75% RD_N + 25% N farm yard manure (FYM); NM_4: 100% RD_{PK}+ 75% RD_N + 25% N *Brassicaceous* seed meal (BSM) and NM_5: 100% RD_{PK}+ 75% RD_N + 25% N neem cake (NC)] and the second one was weed management practices having three levels (weedy, chemical and integrated). Application of concentrated organic manures (BSM and NC) effectively reduced the density and biomass accumulation of weeds at different growth stages of maize. But, weeds like *C. rotundus* and *A. philoxeroides* were not affected due to their hardy nature of propagating materials. The density of predominant weeds of maize crop was drastically reduced in year 2. It may mainly be due to the puddling performed during rice transplanting in crop sequence. By reducing the weed growth, BSM and NC also reduced the nutrient (N, P and K) depletion by predominant weeds of associated crop and hasten the crop growth. As a result, as compared to sole synthetic fertilizer, application of organic manures for 25% N supplementation performed better in enhancing grain yield of maize. The N, P and K uptake by crop produces was also higher with N substitution by organic manures. A linear negative relationship between N, P and K uptake by total weeds and yield of maize crop was noticed. Among different treatment combinations, application of organic manures under integrated weed management approach significantly increased grain yield of maize and also enhanced the system productivity and production efficiency. And this treatment combination also documented the maximum net return and economic efficiency of the system. After experimentation, little improvement of soil organic carbon content and available N, P and K status was noticed with the application of bulky organic manures, *viz.* VC and FYM.

Bio-efficacy of redi-mix herbicides on weed dynamics and crop productivity in late sown wheat under sub-tropical conditions

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Weeds are unwanted intruders into agro-ecosystems that compete with the crops for limited resources and results in reduced crop yields and farmers' income. It was estimated that on an average the weed control costs around INR 6000/ha (USD 92.42/ha) in rainy season crops and around INR 4000/ha (USD 61.61/ha) for winter crops, which accounts for around 33% and 22% of total cost of cultivation, respectively. Therefore, an efficient weed management can help in increasing the farmers' income by reducing the losses caused by weeds, decreasing the cost of production, and increasing the productivity through efficient utilization of resources by controlling all sort of weeds throughout the growing season of crop. Nowadays, weed control is accomplished with the use of herbicides as pre- and post-emergence, applied alone or in a tank mix for efficient control of weeds. A field experiment was conducted in *Rabi* season of 2015-16 and 2016-17, with the aim to evaluate the efficacy of redi-mix herbicides in late sown wheat. The experiment consists of fifteen treatments using randomized block design in four replications. Wheat variety '*Raj 3765*' was used as a test crop. The results showed that tank mix application of sulfosulfuron + metsulfuron 32 g/ha and mesosulfuron + iodosulfuron 14.4 g/ha applied 35 DAS gave maximum per cent reduction in density (90.05 and 88.80%) and dry matter (95.36 and 94.72%) with lowest value of weed index (2.00 and 2.75) and weed persistence index (0.35 and 0.35) of total weeds. Both these treatment recorded maximum 34.3 and 33.3 per cent grain yield enhancement and obtained highest net return (Rs. 63827 and 63226/ha) and benefit:cost ratio (2.34 and 2.32). Mixed application of sulfosulfuron + metsulfuron also results into more uptake of total NPK (102.55, 24.92 and 105.51 kg/ha) by the wheat followed by mesosulfuron + iodosulfuron (99.95, 24.38 and 104.38 kg/ha) at 60 DAS. Further, no symptoms of phytotoxicity were seen in the crop at 21 days after herbicide application in any of the treatment.

Effect of sowing dates and weed management on productivity and profitability of wheat in irrigated plains of Jammu and Kashmir

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Wheat is a major cereal crop grown in India and staple food for billions of people of the world. Yield potential of wheat is not being exploited fully on account of many biotic and abiotic factors. Among various factors, sowing time and weeds infestation are the most important constraints which affect crop productivity. Drastic reduction in yield of wheat has been recorded with the delay of sowing beyond optimum time. It has been estimated that sowing of wheat at the optimum time is of utmost importance for obtaining higher yield and productivity. Delay in sowing increased grain yield losses of wheat due to stiff crop-weed competition and weather conditions favouring some problematic weeds besides reduced vegetative development of the crop. Besides sowing time, infestation of weeds in a crop adversely affect crop production in a number of ways. Weeds compete with crop for available moisture, nutrients, space, light and provide shelter for harmful insect-pests which result in yield reduction. Chemical weed control is a preferred practice due to scarce and costly labour as well as lesser feasibility of mechanical or manual weeding especially in wheat sown with broadcasting method. Therefore, a systematic study on weed dynamics in the crop is essential for strategic weed management planning as timely and effective weed control may be achieved by use of herbicides in wheat which is subjected to various weed densities depending upon weed seed bank diversity in soil.

The field experiment was carried out on wheat at the research farm of Division of Agronomy, Sher-e-Kashmir University of Agriculture Science and Technology, Jammu during the *Rabi* season of 2012-13 and 2013-2014. The experiment was laid out in spilt plot design consisting of two main plot treatments. The main plot treatments consisted of two times of planting *viz.* 15th November and 25th December, while seven weed control methods *viz.* post-emergence application of metribuzin 210 g/ha, sulfosulfuron + metsulfuron 30 g/ha + 2 g/ha, mesosulfuron + iodosulfuron 12 g + 2.4 g/ha, clodinafop-propargyl 60 g/ha, pinoxaden 35 g/ha, weedy check and weed free were taken in sub-plot. The experimental field was severely infested with *Anagallis arvensis*, *Chenopodium album*, *Fumaria parviflora*, *Cirsium arvense*, *Poa annua*, *Phalaris minor, Medicago denticulata* and *Convolvulus arvensis* amongst other weeds. Among sowing dates, 15th November sown crop recorded significantly higher grain yield of 3.81 t/ha as compared to 25th December sown wheat (3.24 t/ha). Post-emergence application of sulfosulfuron + metsulfuron 30 g/ha + 2 g/ha resulted significantly lowest total weed biomass and highest weed control efficiency which led to significant enhancement in grain yield of wheat. Crop sown on 15th November recorded highest net returns of Rs. 60153 per hectare and B:C ratio (2.13) along with post-emergence application of sulfosulfuron + metsulfuron 30 g/ha + 2 g/ha as compared to all other herbicidal treatments treatments.

Weed management in groundnut based (groundnut- wheat) cropping system

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The field investigation on "Weed management in groundnut based (Groundnut-Wheat) cropping system" was carried out in *Kharif* - *Rabi* cropping sequence of the year 2003-04, 2004-05 and 2005-06 at experimental farm of Agricultural Research Station, Kasabe Digraj, Dist. Sangli, under Mahatma Phule Krishi Vidyapeeth, Rahuri, (Maharashtra) with objective to identify the most effective herbicide for groundnut wheat cropping sequence [Crop variety TAG 24 (Groundnut) and NIAW- 301 (Wheat)]. The soil of experimental field was Black clay loam, with FC 38.00 %, PWP 18.00 % and bulk density was 1.2 Mg m^{-3}. The experiment was laid out in Split plot design with three replications and sixteen treatment combinations. The Main plot treatments were: (4) *Kharif* Groundnut. Pendimethalin (stomp) at 1 kg/ha (PE), fluchloralin (basalin) 45 EC at 1 kg/ha (PE), weed free check (3 IC + 2 HW) and farmers practice (2 IC + 1 HW) while the Sub plots treatments were: (4) *Rabi* Wheat. 2,4-D sodium salt at 2 kg/ha (PE), isoproturon (MCPA) at 1.5 kg/ha (PE), weed free check (2 IC + 2 HW) and farmers practice (1 IC + 1 HW).

Pooled results over three years revealed that, the significantly highest groundnut equivalent dry pod yield (4699 kg/ha), gross (Rs. 76871/ha) and net monetary returns (Rs. 36047/ha) with highest B: C ratio (1.94) was recorded with the treatment of weed free check (3 IC + 2 HW) over the season in groundnut crop. However, the same Weed free check (2 IC + 2 HW) treatment recorded the significantly highest groundnut equivalent dry pod yield (4569 kg/ha), gross (Rs. 74220/ha) and net monetary returns (Rs. 34471/ha) with highest B: C ratio (1.91) over the season in wheat crop with lowest weed biomass in both the crops in sequence.

The interaction effects with the treatment combinations G_3W_3 (weed free check - 3 and 2 IC + 2 HW respectively) in the crop sequence of groundnut–wheat recoded significantly highest gross (Rs. 78797/ha) and numerically highest net monetary returns (Rs. 44948/ha) with highest B:C ratio (1.88) than rest of the treatments under study over the seasons.

From the results obtained it can be concluded that the recommended cultural practices for groundnut followed by wheat in sequence observed to be significantly superior for obtaining higher groundnut equivalent dry pod yield, gross and numerically highest net returns and B:C ratio with lowest weed biomass in both the crops in sequence over the seasons over rest of the treatments.

Evaluation of economically feasible weed management option for sunflower under modified spacing

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The field experiments were conducted at Department of Oilseeds, Tamil Nadu Agricultural University Coimbatore, during *Kharif* season, 2016 & 2017 with the objective of to determine the efficient weed control method for modified row spacing of sunflower. The normal recommended spacing for sunflower is 60 x 30 cm, in this spacing operation of power weeder is difficult and it will damage the crop. So, to operate power weeder in sunflower crop spacing was altered as 75 x 25 cm. The experiment was laid out in randomized block design with three replications. The experiment consists seven treatment viz., Pendimethalin at 1.0 kg /ha as PE + power weeder at 30 DAS, two weeding by power weeder at 15 and 30 DAS, pendimethalin as PE spray + Quizalofop-ethyl 10 EC at 37.5 kg/ha as PoE, pendimethalin at 1.0 kg/ha as PE + hand weeding at 30 DAS, T_5 - two hand weeding at 20 and 40 DAS, weed free control and unweeded control. The common weed flora was observed in the experimental field were grasses like *Cynodon dactylon*, *Dacteloctenium aegypticum*, *Echinochloa colona*, *Brachiaria reptans*, *Panicum repens*, *Setaria verticiliata* and common sedge weed dominated was *Cyperus rotundus* and most dominated broad leaved weeds were *Trianthema portulacastrum, Parthenium hysterophorus, Amaranthes viridis*, *Cleome gynandra*, *Digera arvensis*, *Tridax procumbens*, *Acalypha indica*.

The results revealed that weed free environment recorded higher weed control efficiency and it was followed by two hand weeding and pre emergence application of pendimethalin at 1.0 kg/ha *fb* power weeded at 30 DAS. Lowest weed index were recorded in two hand weeding treatment and it was followed by PE pendimethalin at 1.0 kg/ha *fb* power weeded at 30 DAS. The post emergence herbicides controlled grasses but there was no control on the predominant broad leave weeds. Weed free environment resulted in producing significantly higher seed yield of 2301 kg/ha and it was on par with twice hand weeding and pre emergence application of pendimethalin at 1.0 kg/ha *fb* hand weeding or power weeded at 30 DAS. Highest net returns of Rs. 26,399 and benefit cost ratio of 1.64 was observed in pendimethalin at 1.0 kg/ha as pre emergence spray *fb* power weeded at 30 DAS. Hence, to control weeds effectively and economically in sunflower under modified spacing pre emergence application of pendimethalin at 1.0 kg/ha *fb* power weeded at 30 DAS is the best practice.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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A study on dynamics of weed-seed bank and its management in groundnut

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The weed-seed bank is an important part of crop-weed ecology as it is the most important source of annual weeds in cropping systems. These relationships make understanding the weed seed bank even more important for increasing the efficiency of weed management. Understanding the dynamics of weed seed banks is an essential first step in improving weed management plans. This study aims to acquire the information on weed seed bank dynamics and its integrated management by incorporating cultural, physical and chemical methods. Management of weeds in particular area would require prior information regarding weed seed bank which can helpful in designing weed management practices related to a particular micro climate in an area. In principle of reducing weed seed bank, there are three approaches to reduce the seed bank size: i) kill the seeds while they are in the soil (using chemical compounds), ii) stimulate germination of seeds and destroy the seedlings called as 'suicidal' germination, and iii) remove weeds before seed set.

An experiment was conducted at Department of Agronomy, Junagadh Agricultural University, Junagadh (Gujarat) during *Kharif* seasons of 2014 and 2015. The experiment was laid out in split plot design with three replications. The main plots comprised residue management treatments, *viz*. (i) burning of wheat residues, (ii) wheat residue incorporation by rotavator *fb* soil solarization with 25 µm polythene sheet for 15 days and (iii) wheat residue incorporation by rotavator *fb* application of *Trichoderma viride* 5 kg/ha + 20 kg N/ha and sub plots contained weed management treatments, *viz*. (i) stale seedbed (pre-sowing irrigation *fb* Killing the weed flush by subsequent tillage) *fb* IC and HW at 45 DAS, (ii) suicidal germination (Application of ethylene 2000 ppm + KNO_3 2000 ppm with pre-sowing irrigation) *fb* Killing the weed flush by subsequent tillage) *fb* IC and HW at 45 DAS, (iii) pendimethalin 900 g/ha as PRE *fb* IC and HW at 45 DAS, (iv) HW and IC at 15 DAS *fb* pre-mix imazethapyr + imazamox 70 g/ha as POE at 25 DAS, (v) pendimethalin 900 g/ha as PRE *fb* pre-mix imazethapyr + imazamox 70 g/ha as POE at 25 DAS, (vi) weed free and (vii) unweeded check.

Significantly the lowest numbers of total weeds at 30, 60 DAS and at harvest, dry weight of weeds and weed seed bank, lowest weed index and higher weed control efficiency was recorded under the wheat residue incorporation *fb* soil solarization and weed free. Among the weed management, the next superior treatments in this respect were pendimethalin *fb* imazethapyr + imazamox, pendimethalin *fb* IC and HW and suicidal germination *fb* tillage *fb* IC and HW.

Significantly, the highest pod yield (1.47 t/ha) with maximum net returns was recorded under the wheat residue incorporation *fb* soil solarization. Among the weed management, significantly, the highest pod yield (1.68 t/ha) and haulm yield (3.35 t/ha) was recorded under the weed free, which was statistically *at par* with the treatments pendimethalin *fb* imazethapyr + imazamox and pendimethalin *fb* IC and HW with increased magnitude of 124.9 and 124.5%. Conversely, the unweeded check registered significantly the lowest pod yield (0.72 t/ha). Among the weed management, maximum net returns and B:C ratio were achieved with the treatment pendimethalin *fb* IC and HW and closely followed by the treatment weed free, pendimethalin *fb* pre-mix imazethapyr + imazamox and suicidal germination *fb* tillage *fb* IC and HW.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Evaluation of post-emergence herbicides for weed control in castor

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Weed management is among the main factors limiting cultivation of castor, particularly when labour is scarce or expensive. Selective post-emergence herbicides are needed in castor as limited pre-emergence herbicides are available to growers, and weed escapes will occur in castor production when fops are used against grasses. Therefore, identification of selective post-emergence herbicides for broad-leaf weed control in castor and to evaluate its tolerance to these herbicides will broaden the herbicides basket for castor. A field experiment was carried out at the ARS, Darsi, Prakasam District, A.P. during the *Rabi* 2015-16 and 2016-17 to find out the most suitable weed management practice in castor. The experiment consists of 9 treatments involving various combinations of pre and post-emergence herbicides along with other methods of weed management practices and laid out in RBD with three replications. Castor was sown in the first week of October at 90 cm wider rows at 60 cm distance by dibbling the seeds at 5-6 cm depth. Only single plant was allowed to grow from each hill by thinning by two weeks after sowing. A popular private hybrid '*MRCA- 409*' was used as test variety. Pre-emergence herbicide pendimethalin was applied at 1.0 kg/ha immediately after sowing at 70-80% of field capacity in the red soil. Post-emergence herbicide chlorimuron-ethyl was applied on actively growing young weed plants at 30 days after sowing as over the top application. Regular irrigations were given as and when required to avoid moisture stress during the crop growth season. The predominant weed flora recorded in the experiment were *Trichodesma indicum*, *Trianthema portulacastrum*, *Chorcorus* sp., *Phyllanthus niruri*, *Digera arvense*, *Cyperus rotundus*, *Boerhevia diffusa*, *Parthenium hysterophorus etc.*

Hand weeding at 20 and 40 days after sowing leads to highest weed control efficiency and markedly superior over all other treatments. Pre-emergence application of pendimethalin at 1.0 kg/ha *fb* chlorimuron-ethyl at 10 g/ha as POE at 30 DAS gave highest kernel yield (1054 kg/ha) and was comparable with hand weeding twice at 20 and 40 DAS (1099 kg/ha). Further the net returns (Rs. 12,015) and benefit cost ratio (1.30) with pendimethalin at 1.0 kg/ha as PE *fb* chlorimuron- ethyl at 10 g/ha as POE at 30 DAS were higher than hand weeding twice at 20 and 40 DAS (Rs. 5215 and 1.11, respectively).

The treatment received pendimethalin *fb* chlorimuron-ethyl at 10 g reduced the weed growth significantly and gave comparable kernal yield (1054 kg/ha) and higher net returns (Rs. 12,015) and benefit cost ratio (1.295) than the hand weeding twice in castor. Results of the study indicated that castor tolerance to PE application of pendimethalin at 1.0 kg/ha *fb* chlorimuron- ethyl at 10g/ha as POE at 30 DAS was excellent, thus providing the greatest opportunities for quick control of broad-leaved weeds selectively in castor.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Tank mix application of early post-emergence herbicides for efficient weed control and higher economics in irrigated groundnut

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Weed competition is going to be the major constraints in achieving higher productivity in groundnut crop under irrigated condition. The yield loss due to weeds range from 15 to 30%, due to shortage of labour or scarcity of water and energy, electricity *etc.* It is necessary to incorporate the chemical methods aimed at inhibiting the metabolic processes, in integrated weed management practices. In order to evaluate tank mix application of early post-emergence herbicides for efficient weed control in groundnut under irrigated condition, two field experiments were conducted during *Rabi* 2014-15 and *Kharif* 2015 at Perunthalaivar Kamaraj Krishi Vigyan Kendra (PKKVK), Puducherry State experimental farm in a randomized block design with three replications. The soil type was red sandy loam in texture, acidic in reaction (pH 6.02) and electrical conductivity (EC) of 0.03 dSm-1 with groundnut variety '*JL 24*', during *Rabi* 2014- 15 and 'G-6', during *Kharif*. Twelve treatments *viz.*weedy check, farmers practice (hand weeding at 15 and 30 DAS), pendimethalin 1.5 kg /ha (pre-emergence) + one hand weeding at 25-30 DAS, pendimethalin 1.5 kg/ha (pre-emergence) + imazethpyr 75 g/ha at 20-30 DAS, pendimethalin 1.5 kg/ha (pre-emergence) + quizalofop-ethyl 50 g/ha at 20-30 DAS, pendimethalin 1.5 kg/ha (pre-emergence) + tank mix of imazethpyr (50%) + quizalofop-ethyl (50%) at 20-30 DAS, pendimethalin 1.5 kg/ha (pre-emergence) + tank mix of imazethpyr (60%) + quizalofop-ethyl (40%) at 20-30 DAS, pendimethalin 1.5 kg/ha (pre-emergence) + tank mix of imazethpyr (40%) + quizalofop-ethyl (60%) at 20-30 DAS, tank mix of imazethpyr (50%) + quizalofop-ethyl (50%) at 20-30 DAS, tank mix of imazethpyr (60%) + quizalofop-ethyl (40%) at 20-30 DAS, tank mix of imazethpyr (40%) + quizalofop-ethyl (60%) at 20-30 DAS and weed free check were tested. Results showed that among the different treatments, the highest pod yield of 3.87 t/ha and 3.58 t/ha was recorded with application of pendimethalin 1.5 kg/ha (pre-emergence) + tank mix of imazethpyr (40%) + quizalofop-ethyl (60%) at 20-30 DAS (post-emergence) in groundnut. Similarly, highest B:C ratio 2.99 and 2.66 was obtained with this treatment.

Weed management in groundnut

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Groundnut or peanut (*Arachis hypogaea* L.) is known as the 'king' of oilseeds. It is one of the most important food and cash crop of our country. Groundnut is also called as wonder nut and poor men's cashew nut. Predominant weeds identified in groundnut fields were *Chloris barbata*, *Panicum repens* and *Dactyloctenium ageyptium* among grasses. Among the sedges, *Cyperus rotundus and Cyperus esculentus* were predominant. Major broad-leaved weeds were *Celosia argentia*, *Trianthema portulacastrum*, *Tridax procumbens*, *Euphorbia geniculata*, *Digera arvensis*,*Parthenium hysterophorus*, *Portulaca oleraceae* and *Phyllanthus niruri*. Peanut is highly susceptible to weed infestation because of its slow growth in the initial stages upto 45 DAS, short plant height and underground pod bearing habit. Unlike other crops, weeds interfere with pegging, pod development and harvesting of groundnut during different stages of crop growth besides competing for essential resources. Therefore, weeding has to be completed before pegging process. Peanut weeds comprise diverse plant species from grasses to broad-leaf weeds and sedges and cause substantial yield losses (15-75%) which are more in bunch type than in spreading groundnut. The most critical period of weed competition is from three to six weeks after sowing. The increased plant height, reduction in leaf area and crop dry matter production and inhibition of pegging in groundnut due to severe weed infestation is reported which ultimately contributes to reduced productivity and yield. Since a wide range of weed and intensity of weeds are prevalent in groundnut field no single method is effective in controlling weeds. It advocates to adopt combination of several weed control measures which includes both direct and indirect methods such as land preparation, water management, planting method and fertility management that can help in controlling weeds below threshold level. Manual and mechanical methods of weed control, besides being less effective, costly and time demand as well as need to be repeated at frequent intervals. Chemical weed control is a better supplement to conventional methods and forms an integral part of the modern crop production cultivation and various physical, chemical and mechanical methods that curtail the growth and spread of weeds. The common weed management practice for groundnut is pre-emergence application of selective herbicides like pendimethalin or fluchloralin followed by one hand weeding. Thus, use of herbicides is one of the options left with the farmers to eliminate crop weed competition at early growth stage of crop. The nature of weed spectrum in groundnut, competition between crops and weeds, their effect on growth and yield determines the different weed management practices for groundnut.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Effect of weed management practices on growth and yield of rainfed greengram

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The experimental study was conducted during *Kharif*, 2015 and 2017 at Agricultural Research Station, Madhira, Khammam district, Telangana to study the effect of different weed management practices on weed growth and yield of greengram in rainfed situation. The experiment has eleven treatments application of pendimethalin 1.0 kg/ha as pre-emergence, imazethapyr 50 g/ha at 2-3 weed leaf stage, chlorimuron ethyl 3.5 g/ ha as pre-emergence, imazethapyr 70 g/ha as pre-emergence followed by quizalofop ethyl 50 g/ha at 2-3 weed leaf stage, imazethapyr 80 g/ha as pre-emergence followed by quizalofop ethyl 50 g/ha at 2-3 weed leaf stage, chlorimuron ethyl 3.5 g/ha as pre-emergence followed by imazethapyr 70 g/ha at 2-3 weed leaf stage, chlorimuron ethyl 3.5 g/ha as pre-emergence followed by imazethapyr 80 g/ha at 2-3 weed leaf stage, chlorimuron ethyl 2.5 g/ha as pre-emergence followed by imazethapyr 70 g/ha at 2-3 weed leaf stage, chlorimuron ethyl 2.5 g/ha as pre-emergence followed by imazethapyr 80 g/ha at 2-3 weed leaf stage, hand weeding twice at 15 and 30 DAS and weedy check which are replicated thrice in randomized block design. The results of pooled data for two years exerted as the higher weed population was observed in weedy check (7 no./ m^2) at 15 DAS as compared to other treatments. This might be due to early emerging weeds were controlled with herbicides applied as pre-emergence. At 30 and 45 DAS, post emergence application of imazethapyr 70 and 80 g/ha was controlled most of the broad-leaved weeds except grassy weeds which were controlled effectively with the application of quizalofop ethyl 50 g/ha as post-emergence. At 15 DAS, significantly lower weed dry matter production recorded in herbicidal treatments than weedy check which might be due to lower weed growth in treatments of pre-emergence herbicides. Whereas at 30 and 45 DAS, comparatively lower weed dry matter was recorded in imazethapyr 70 g/ha as pre-emergence followed by quizalofop ethyl 50 g/ha at 2-3 weed leaf stage and imazethapyr 80 g/ha as pre-emergence followed by quizalofop ethyl 50 g/ha at 2-3 weed leaf stage than other treatments. This might be due to effective control of broad spectrum of weeds at critical crop growth stage. Hence, these both the treatments produced higher yield attributes pods/plant, seeds/ pod, test weight and inturn they produced higher yields 1228 and 1127 kg/ha respectively which are on par each other. Similarly these treatments were projected as on par results in getting the higher gross returns (Rs. 85936/ ha and 78851/ha), net returns (Rs. 57574/ha and 50454/ha) and B:C ratio (Rs. 2.0 and 1.8) in greengram during rainfed situation.

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Effect of integrated weed management in pigeonpea

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The experiment on effect of integrated weed management in pigeonpea was conducted during *Kharif* seasons of the year 2013, 2014 and 2015 at Pulses Improvement Project, MPKV, Rahuri. The experiment was laid out in randomized block design with three replications. The seven weed management treatments in pigeonpea were *viz*., pendimethalin at 0.75 kg/ha on 3 DAS + one HW on 50 DAS, imazethapyr at 100 g/ha on 10-15 DAS + one HW on 50 DAS, quizalifop ethyl at 100 g/ha 10-15 DAS + one HW on 50 DAS, pendimethalin at 0.75 kg/ha on 3 DAS + imazethapyr at 100 g/ha on 10-15 DAS, pendimethalin at 0.75 kg/ha on 3 DAS + imazethapyr at 100 g/ha on 10-15 DAS + one HW on 50 DAS, pendimethalin at 0.75 kg/ha on 3 DAS + quizalifop ethyl at 100 g/ha 10-15 DAS and pendimethalin at 0.75 kg/ha on 3 DAS + quizalifop ethyl at 100 g/ha 10-15 DAS + one HW on 50 DAS. Pendimethalin at 0.75 kg/ha on 3 DAS + imazethapyr at 100 g/ha on 10-15 DAS + one HW on 50 DAS produced significantly higher pigeonpea grain yield (2179, 2061, 2208 and 2149 kg/ha), B:C ratio (2.85, 3.26, 3.80 and 3.30), weed control efficiency at 50 DAS (85.24, 86.87, 73.83 and 81.98%) and 70 DAS (78.53, 61.43, 86.45 and 75.47%) while significantly lower dry matter of weeds at 30 DAS (28.37, 29.57, 23.80 and 27.24 g), at 50 DAS (18.70, 18.63, 35.53 and 24.29 g) and at 70 DAS (69.53, 67.93, 15.09 and 50.85 g) than other weed management treatments during the year 2013-14, 2014-15, 2015-16 and on pooled mean basis, respectively.

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Effect of pre- and post-emergent herbicides on growth and yield of Urdbean under acidic soils of Manipr

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A field experiment was conducted at C.A.U. Research farm, Andro, Imphal East of Central Agricultural University, Manipur during *Kharif* season 2016 and 2017. It was laid out in randomized block design with nine different herbicide treatments *viz*. Unweeded control, pendimethalin at 1.0 kg/ha PE, pendimethalin + imazathapyr at 1 kg/ha, imazethapyr at 55 g/ha at 15 DAS, imazamox + imazethapyr at 40, 60 g/ha at 15 DAS, clodinafop propargyl + aciflourfen sodium at 125, 187.5 g/ha at 15 DAS and twice hand weeding at 20 and 40 DAS. The results indicated that hand weeding twice at 20 and 40 DAS recorded significant reduction in weed count, weed dry matter and weed control efficiency followed by the pre-emergent application of pendimethalin + imazathapyr at 1 kg/ha. Significantly higher number of pods per plant, seed and stover yield, significantly higher seed yield, stover yield, number of pods per plant and growth attributes like plant height and number of branches per plant and total dry matter accumulation per plant recorded with application of pendimethalin + imazathapyr at 1 kg/ha followed by clodinafop propargyl + aciflourfen sodium at 187.5 g/ha at 15 DAS. From two year of field trials, it is concluded that either pre-emergent application of ready mixture of pendimethalin + imzathapyr at 1 kg/ha + one hand weeding at 25-30 DAS or clodinafop propargyl + aciflourfen sodium at 187.5 g/ha at 15 DAS is the most effective treatment in controlling weeds and increase the productivity of urdbean under acidic soils of Manipur.

Influence of pre- and post-emergence herbicide on growth, yield and quality of blackgram

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The field investigation entitled "Influence of pre and post emergence herbicide on growth yield and quality of black gram" conducted during *Kharif* at college farm, Department of Agronomy, College of Agriculture, Latur. The soil of the experimental site was clayey, alkaline in reaction, low in organic carbon and available nitrogen, medium in available phosphorus and high in available potash. The soil was well drained with moderate moisture retention capacity which was favourable for optimum growth. The environmental conditions were moderately congenial for growth and development of black gram. crop experiment was layout in randomized Block Design with eight different weed control treatments *viz.*, Un weeded (control), one hand weeding DAS, weed free, oxyflurfen EC at kg/ha (PE), pendamethalin EC at kg/ha (PE), quizalofop ethyl + imazethapyr 5 EC at kg/ha (POE), quizalofop ethyl + imazethypyr (POE) replicated thrice. The gross and net plot size of each experimental unit was 5.4 x 4.2 m and 4.4 x 3.6 m respectively with spacing 30 x 10 cm. Sowing was done by dibbling method on 10th July 2014 .The recommended dose of fertilizer 25:50:00 NPK kg/ha was applied. The recommended dose of fertilizers (nitrogen and phosphorus) was applied through Urea and SSP. The crop was harvested on 20th September 2014. Among the chemical weed control methods, application of imazethapyr 10 SL at kg/ha had controlled the weeds more effectively in black gram crop which helps improving growth, yield, quality attributes, weed control efficiency, weed index with obtaining higher returns. Hence, it is proposed apply imazathapyr 10 SL at 0.10/ha. To the control the weed in black gram and for getting higher yield.

Screening of blackgram varieties for their weed competitiveness and tolerance to pre- and post-emergence herbicidal application during *Rabi* season

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In R*abi* blackgram, grown under receding soil moisture in black soils, weed management is important. Pre and post-emergence herbicidal application is common. However, varieties differ in their ability to compete with weed species depending on their early vigour, growth habit, smothering capacity and thus withstand the weed competition. Further, response to post-emergence herbicide application in blackgram may vary with the varietal tolerance. Hence, a field study was taken up to screen varieties for their weed competitiveness and tolerance to post-emergence herbicidal application under upland situation during *Rabi* season. A field experiment was carried out at Regional Agricultural Research Station, Lam, Guntur, Andhra Pradesh, with an objective to find out the competitive ability of blackgram varieties to smother weeds during *Rabi* season of 2015-16 and 2016-17 under upland conditions. The experiment was laid out in split plot design with three replications. The treatments consisted of five methods of weed control as main plots, *viz.* pendimethalin 1.0 kg/ha as pre-emergence, imazethapyr 50 g/ha as post-emergence, pendimethalin 1.0 kg/ha *fb* imazethapyr 50 g/ha, manual weeding at 20 and 40 days after sowing along with inter cultivation at 30 days, unweeded and four blackgram varieties, *viz.* '*GBG 1*' ' *PU 31*' ' *LBG 787*' '*LBG 752*' as sub treatments which were replicated thrice. Weed dry matter recorded at 45 days with pre-emergence application of pendimethalin 1.0 kg/ha *fb* imazethapyr 50 g/ha was 4.51 g/m^2 and was on par with manual weeding treatment with intercultivation (4.37 g/m^2) followed by pre-emergence application of pendimethalin 1.0 kg/ha application and imazethapyr 50 g/ha which were on par with each other. All the varieties were comparable and equally effective in controlling the weed dry matter. Plant height was not influenced by weed management treatments. However, the varieties, '*LBG 787'* and '*LBG 752'* recorded higher plant height. Yield attributes, *viz.* number of pods per plant was more with pendimethalin 1.0 kg/ha *fb* imazethapyr 50 g/ha and manual weeding treatment with intercultivation. The variety '*GBG 1*' recorded significantly higher 100 seed weight (4.56 g). No significant difference in grain yield was observed with response to blackgram varieties, *viz.* '*GBG 1*' ' *PU 31*' ' *LBG 787*' '*LBG 752*' to the application of pre-emergence pendimethalin 1.0 kg/ha, post-emergence application of imazethapyr 50 g/ha or a combination of both. Among the weed control methods, manual weeding treatment with intercultivation gave significantly higher yield (709 kg/ha) followed by post-emergence application of imazethapyr 50 g/ha (546 kg/ha) and a combination of pre-emergence pendimethalin 1.0 kg/ha *fb* imazethapyr 50 g/ha (564 kg/ha). Further, varieties '*GBG 1*' (748 kg/ha) and '*PU 31*' (780 kg/ha) performed better in manual weeding treatment with intercultivation and without any herbicide use.

Growth and yield of blackgram as influenced by weed management with different doses of phosphorus and potassium

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One of the major constraints in black gram production is weed infestation. The losses caused by weeds vary depending on the floristic composition, intensity, density and geometry of crop, environmental and crop management practices followed. Hence, timely removal of weeds using suitable method in appropriate time is essential to get high yield of black gram. Among the production inputs, fertlization plays important role in enhancing productivity levels. Black gram being a leguminous crop, does not require nitrogen fertilizer except a starter dose since it can fix atmospheric nitrogen. However, it repsond well to phosphorus and potassium nutrient where application of these nutrients in soils results in rapid growth, maturity and enhances the quality of the crop. With this view, a field experiment was conducted in Agronomy experimental farm, SASRD, Medziphema, Nagaland to study the effect of weed management in black gram with different doses of phosphorus and potassium. The experiment was laid in factorial randomized block design with three replications. The treatment comprised of three weed management practices with a control, *viz.* weedy check (control), hand weeding at 25 DAS and 45 DAS, pendimethalin 0.75 kg/ha *fb* hand weeding at 25 DAS, pendimethalin 0.75 kg/ha *fb* imazethapyr 0.5 kg/ha at 25 DAS. Three doses of phosphorus and potassium were taken, *viz.* 30 kg/ha P_2O_5 and 30 kg/ha K_2O, 40 kg/ha $P_2O_5$and 40 kg/ha K_2O and 50 kg/ha P_2O_5 and 50 kg/ha K_2O. Single superphosphate and muriate of potash was used as the source of phosphorus and potassium, respectively. The results of the experiment showed that the dominant broad-leaf weeds found were *Ageratum conyzoides, Commelina benghalensis, Phyllanthus niruri, Amaranthus viridis, Chromalaena odorata* and *Mimosa spinosa*. *Cyperus iria* and *Cyperus rotundus* were the common weeds among sedge weeds and among the grassy weeds, *Digitaria sanguinalis, Eluesine indica* and *Echinochloa colona* were the dominant weeds where black gram was grown. Hand weeding at 25 DAS and 45 DAS gave the maximum decrease in weed density and dry weight in all the categories of weeds and hence gave the highest value in plant height, number of primary branhces/plant, leaf area index, number of pods/plant, number of seeds/pod and consequently gave the highest seed (1.49 t/ha) and stover yield of black gram which was followed by pendimethalin 0.75 kg/ha *fb* hand weeding at 25 DAS (1.39 t/ha). The lowest seed yield was obtained in weedy check (0.53 t/ha). Application of different doses of phosphorus and potassium also gave significant effect on the growth and yield of black gram where appliaction of 40 kg/ha P_2O_5 and 40 kg/ha K_2O recorded the highest seed yield of black gram which was staistically at par with application of 50 kg/ha P_2O_5 and 50 kg/ha K_2O. However, the lowest seed yield was recorded in application of 30 kg/ha P_2O_5 and 30 kg/ha K_2O.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Bio-efficacy of fomesafen + fluazifop-p-butyl mixture against weeds in soybean

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A field experiment entitled "Efficacy of fomesafen + fluazifop-p-butyl mixture against weeds in soybean, their persistence and residual effect on succeeding wheat crop in vertisol" was conducted at Product Testing Unit, Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during *Kharif* 2017. The ten weed control treatments comprising of four doses of fomesafen + fluazifop-p-butyl mixture (90 + 90, 110 + 110, 130 + 130 and 220 + 220 g/ha), alone application of imazethapyr (100 g/ha), market check – fomesafen + fluazifop-p-butyl (110 + 110 g/ha), combined application imazethapyr + imazamox (35 + 35 g/ha) as early post-emergence, hand weeding twice at 15 and 30 DAS, weed free and weedy check, were laid out in randomized complete block design with 3 replications. It is obvious from the data that the experimental field cropped with soybean was infested with rampant weeds *Echinochloa colona* (35.37%) and *Mollugo pentaphyla* (25.00%). However, other weeds like *Cyperus iria, Cichorium intybus, Phyllanthus urinaria, Eclipta alba* were also present in less numbers. The control plots receiving no weed control treatment had maximum weed density (128.00 and 145.33/m^2) and dry weight (106.18 and 18.16/m^2) of monocot and dicot weeds respectively. Early post-emergence application of the lowest dose of fomesafen + fluazifop-p-butyl mixture (90 + 90 g/ha) caused appreciable reduction in density and dry weight of monocot (86.74% WCE) as well as dicot weeds (90.94% WCE). However, the activity of mixture was further increased with corresponding increase in dose being higher (96.25 and 96.46% WCE of monocot and dicot respectively) when it was applied at 110 + 110 g/ha or higher rate 130 + 130 g/ha (99.23 and 99.21% WCE) and proved significantly superior over market sample of fomesafen + fluazifop-p-butyl mixture at 110 + 110 g/ha (94.71 and 95.36% WCE), imazethapyr alone at 100 g/ha (87.00 and 76.52% WCE) being at par to weed free and hand weeded plots. The seed yield was minimum (0.68 t/ha) in the plots receiving no weed control measure but it was increased markedly in the plots receiving fomesafen + fluazifop-p-butyl mixture at 90 + 90 g/ha (1.21 t/ha). However, the yield was further increased with corresponding increase in dose of fomesafen + fluazifop-p-butyl mixture being the maximum when it was applied at 130 + 130 g/ha (2.01 t/ha) and proved significantly superior over the check herbicides imazethapyr 100 g/ha (1.04 t/ha), market sample of fomesafen + fluazifop-p-butyl mixture 110 + 110 g/ha (1.62 t/ha), imazethapyr + imazamox 35 + 35 g/ha (1.46 t/ha), but found at par to higher dose of fomesafen + fluazifop-p-butyl mixture 220 + 220 (1.98 t/ha), weed free (2.04 t/ha) and hand weeding twice (1.99 t/ha).

Major weeds and their management in fodder crops

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Like food crops weed is an important constraint for fodder production. Weeds not only reduce the total fodder production but also impair the quality of fodder. Weeds like *Trianthema* spp., *Coccinia grandis, Amaranthus viridis* and *Spilanthes calva* when appeared in fodder maize and sorghum during summer and rainy seasons, the quality and total green fodder yield got reduced significantly. Other weeds *Cichorium intybus*, *Rumex dentatus* and *Coronopus didymus* in berseem and *Celosia argentea* in summer fodder cowpea drastically reduced the quality and total green fodder yield.

Among the weeds *Trianthema* was widely distributed in fodder farm (300 acres land) of IVRI, Izatnagar, mainly because of its strong character on seed production and multiplication both by seed and vegetative means. Each *Trianthema* flower produced 224 to 504 seeds/plant. 2 to 3% of the total current seeds germinated within 6 days after imbibition, majority of the seeds germinated within 17 to 20 days after imbibition and remaining seeds germinated afterwards. 10 days old plant of *Trianthema* was controlled through stale seedbed technique and beyond that stage fragmented plant parts put forth the new growth. The mature plant of *Celosia argentea* produced 1,716 to 3,496 seeds/plant when it was associated with fodder sorghum. One mature *Coccinia grandis* plant produced 2934 to 4428 seeds/plant and *Cleome viscosa* produced 672 to 1755 seeds/plant. Seeds of *Trianthema* spp., *Coccinia grandis, Rumex dentatus* and *Cleome viscosa* have shown the character of endozoochory mechanism and passed through the cattle rumen successfully. The seeds became viable into fresh cattle dung. Application of undecomposed manure/FYM disseminated these weeds into the fields. Three major broad-leaved weeds *Coronopus didymus*, *Rumex dentatus*, *Cichorium intybus* appeared during 1st, 2nd, 3rd and 4th cutting of berseem, respectively.

Growing of fodder cowpea in the place of fodder sorghum recorded almost 86% reduction on seed production of *Celosia argentea.* Berseem cultivation during winter season under puddled condition reduced infestation of *Coccinia grandis* during summer and rainy seasons. Mixed cropping of berseem + gobhi sarson (*Brassica napus var. napus)* and berseem + makkhan grass/rye grass recorded higher green fodder yield and also suppressed the growth of *Coronopus didymus* the major weed in winter fodder crops. Mixed cropping of maize + cowpea has recorded weed smothering capacity and shown complementary effect on total green fodder yield up to 55-60 days after sowing beyond that cowpea showed supplementary and competitive effect on fodder maize. *Panicum maximum* has shown the capacity to suppress the growth of *Parthenium* in non-crop area. VL Gehun 829 has been identified as a promising dual purpose wheat variety for grain-cum-green fodder yield and also controlled the weeds *Phalaris minor* and *Rumex dentatus* effectively due to cutting of wheat for green fodder. The varieties JO-1 and JHO-822 were recorded as promising varieties of oat based on green fodder yielding capacity and weed suppression capacity. Use of higher seed rate of 63 kg/ha of fodder maize along with the use of ferti-seed-drill was equally effective with atrazine treatment in controlling weeds, producing higher green fodder yield and obtaining more profit. Both pre- and post-emergence treatments of atrazine at the doses of 0.50, 0.75, 1.0 and 2.0 kg/ha became effective in controlling weeds in fodder maize and sorghum, however, residue levels of atrazine at all the corresponding doses were detected with the values of 0.1296 µg/g, 0.2118 µg/g, 0.5445 µg/g and 0.8109 µg/g, respectively, at 38 days after application in green fodder sorghum and 0.0081 µg/g, 0.0137 µg/g, 0.1810 µg/g and 0.5310 µg/g, respectively, at 60 days after application in green fodder maize.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Challenges and opportunities of weed management in sugarcane

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About 78% of world sugar demand is met from sugarcane, which is grown in more than 80 countries with a production of 11.8 million tonnes of sugar. India ranks second, after Brazil, in area and production of sugarcane in the world. It is also the most important sugar crop in India occupying an area of 5.03 Mha (3.5 per cent of net cultivated area) with an average productivity 70.86 t/ha, and contributes about 0.69 per cent to national GDP. Its grown as main crop as well as a ratoon crop. As ratoon crop it occupies about 50% of total sugarcane area with an average productivity of 50 t/ha. In addition to this, millions of farm families are directly or indirectly associated with this crop. The sugarcane crop is grown in two distinct agro-climatic zone of the country *i.e.* tropical and sub-tropical. Uttar Pradesh, Maharashtra, Karnataka, Gujarat, Andhra Pradesh and Tamil Nadu are the major sugarcane growing states contribute about 81% of the total production in India. Among several problems faced in sugarcane cultivation, weeds are identified as one of the serious factors responsible for low yields in sugarcane to the extent of 38 to 76%. Weeds are considered one of the most important yield limiting factors causing more than 45% loss in yields of field crops, as compared to 25% due to diseases, 20% due to insects, 15% due to storage and miscellaneous pests and 6% due to rodents. Weeds poses severe competition to sugarcane crop due its, wide spacing, slow germination and growth at initial stages, heavy fertilization and frequent irrigations. It severely reduces not only the tonnage, but also its quality besides hindering in the various field operations and harbouring insect-pests and disease. The nature of weed problem in sugarcane cultivation is quite different from other field crops because of inherent capacity of slow initial crop growth and heavy input requirements. The crop is infested with almost all types of weeds *viz,* grassy, broad-leaved weeds and sedges. In addition to these, twining and parasitic weeds are also threatening and leads to difficulty in harvesting. Owing to heavy nutrient application and frequent irrigation favours emergence of more flush of weed flora in the same growing season. It takes about 30-45 days to complete germination and another 60-75 days for developing full canopy cover. The initial 60-120 days period of crop growth is considered as most critical period of crop-weed competition. There are several perennial weeds like *Sorghum halepense*, *Cyperus rotundus*, *Cynodon dactylon*, *Striga* sp causing immensely losses in plant and ratoon cane crop in the tropical and subtropical regions of the country as well as the world. These weeds are so damaging that the losses can be experienced as high as 90% of the total crop yield in various part of the world. Although weeds are a challenge in the current sugarcane production system in India, there are many opportunities exist for developing sustainable and effective weed management programmes for main and ratoon crop. In depth studies are needed on weed ecology and biology, especially in understanding the seed bank dynamics in different locations and cropping systems under changing climatic scenario to formulate an effective and sustainable weed management strategies. A huge quantity of trashes ranging from 12-15 tons/ha can be effectively utilized as a component of IWM practices besides improving the resource use efficiency. There are several weed management techniques which may be started much before planting as a preventive measure and may continue in the standing field crop by way of physical, mechanical, and chemical methods of weed management to improve the cane yield and farmer income.

Screening of herbicides for selectivity in irrigated flue cured tobacco grown in alfisols of Andhra Pradesh

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Tobacco in India is cultivated in about 4.93 lakh hectares (0.24% of total arable land) comprising of different styles/types of tobaccos used for different purposes like making cigarette, bidi, chewing, hookah, cheroot, cigar wrapper and filler with an estimated production of 800 Million Kg (M Kg). Flue cured tobacco accounts for about 265 M Kg, which is produced in 2.17 lakh hectares in Andhra Pradesh and Karnataka.Weeds are one of the major limiting factors in cultivation of agricultural corps and are responsible for declining crop productivity to an extent 10-80% besides impairing product quality and causing health and environmental hazards. Weeds directly compete with tobacco for light, water, nutrients, carbon dioxide, and space and adversely impact its yields. In addition, the quality of the final product may be further affected due to the presence of foreign plant material, referred to in the tobacco industry as Non-Tobacco Related Material (NTRM). Natural infestations of weeds that were allowed to compete with dark tobacco for the entire season resulted in a 28% to 40% reduction in total yield compared to tobacco plots treated with herbicides. Since tobacco is sensitive to herbicides, the criteria for selection of appropriate herbicide that can be used on tobacco should have high degree of selectivity, without causing phytotoxicity. Extensive global studies on tobacco weed control identified clomazone, metolachlor, napropamide and pebulate offering high degree of weed control and most suitable for tobacco. The objective of the study was to identify herbicides registered in India which can potentially provide weed free environment in tobacco during critical period of crop growth. The following pre- and post-emergence herbicides comprising of pendimethalin, alachlor, oxyflourfen, sodium acifluorfen + clodinafop propargyl, tembotrione, penoxsulam + cyhalofop-butyl, topramezone, ethoxysulfuron, bentazone and propaquizafop were tested for phytotoxicity in FC tobacco. Among herbicides evaluated, pendimethalin (1 kg/ ha), alachlor (0.75 kg/ha) and propaquizafop (0.75 kg/ha) had shown no phytotoxicity on a rating scale of 0-10.

Effect of seed rate, row spacing and herbicide on weeds and yield of flax fibre

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Flax (*Linum usitatissimum* L.) fibre is amongst the oldest fibre crops in the world after silk its fibre is pale yellow in colour, soft and lustrous but less flexible and stronger than cotton. It absorbs and releases water quickly making linen comfortable to wear in hot weather. The best grades are used for linen fabrics and coarser grades are used for the manufacturing of twine and rope. In India the flax is being cultivated for oil seed on residual moisture after harvest of rice and border row of many winter pulses. Its cultivation for fibre has not been yet commercialised. Though, the demand of flax fibre has increased in recent past due to bad impact of synthetic fibre used for packaging, bags, *etc.* on environment. Hence, there is need to increase the production of as flax fibre crop. Weeds are one of the major constraint for enhancing the productivity as it reduced about 20-30% of flax fibre if not controlled because it is weak competitor of weeds. Herbicides which are economical practice of weed control is scare for flax fibre, hence, cultural practices like manipulation in seed rate, row spacing, intercropping date of sowing *etc.* may the alternative options for reducing the weed completion on flax fibre crop. A experiment was conducted in spilt-split plot design with four seed rate (40, 60, 80 and 100 kg/ha) in main plot, two row spacing (20 and 30 cm) in sub-plot and four weed control practices (two hand weeding, pendimethalin 0.75 kg/ha pendimethalin 1.0 kg/ha and weedy check) in sub sub-plot with three replication in ICAR-CRIJAF Barrackpore.

Experimental plot was infested with a sedge *Cyperus rotundus,* a grass weed, *Echinochloa colonum* and broad-leaved weeds, *viz.*, *Chenopodium album, Meliotus indica*, *Medicago denticulata*, *Angallis arveisis. Gnaphalium* sp. Weed density and its dry weight reduced significantly by different seed rate of flax. Significantly lower weed density and dry weight were recorded in seed rate of 100 kg/ha. Lower weed density was also recorded in 20 cm of row space though, the reduction was non-significant. Reduction in weed density and dry weight was higher in pendimethalin 1.0 kg/ha and it was at par with pendimethalin 0.75 kg/ha. The maximum height of flax (91.6 cm) was in low seed rate (40 kg/ha) and minimum height in higher seed rate (100 kg/ha). Row spacing did not affect significantly the plant height but maximum height in 20 cm row spacing. Among weed control practices, maximum plant height in two hand weeding (90 cm) and it was at par with pendimethalin 0.75 kg/ha the lowest plant height was obtained din weedy check. Maximum fibre yield (2.19 t/ha) was recorded with 100 kg/ha seed which was significantly higher than low seed rate and at par with 80 kg/ha. Fibre yield did vary significantly in row spacing. The highest fibre yield was recorded in two hand weeding (2.33 t/ha) followed by pendimethalin 0.75 kg/ha (2.15 t/ha).

It may be concluded that flax fibre sown with seed rate of 80 kg/ha at 20 cm row spacing and application of pendimethalin 0.75 kg/ha effectively controlled the weeds resulted in significantly higher flax fibre yield.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Weed management in bidi tobacco (*Nicotiana tabacum* L.) nursery

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Tobacco (*Nicotiana tabacum* L.) is the most widely grown commercial non-food crop in the world. Among various types of tobacco, bidi tobacco shares about 30% of total tobacco area and about 40% of tobacco production in the country. Gujarat stands first in bidi tobacco production in India. Raising nursery is an important aspect of bidi tobacco cultivation. Weeds are the major problem of healthy bidi tobacco seedlings in Gujarat soils. During *Kharif* season, simultaneous emergence and rapid growth of weeds along with bidi tobacco seedlings in seed beds cause severe crop-weed competition.

A field experiment entitled 'Weed management in bidi tobacco (*Nicotiana tabacum* L.) nursery' was conducted during *Kharif* season of the year 2016 at Bidi Tobacco Research Station, Anand Agricultural University, Anand, Gujarat which is geographically located at 22^0 352 north latitude and 72^0 562 east longitude at an elevation of about 45.1 meters above the mean sea level. The experiment was carried out in randomized block design (RBD) with twelve treatments and three replications. The treatments comprised of control (weedy check), hand weeding at 15, 30 and 45 DAS, hand weeding at 20 and 40 DAS, rabbing with bajra husk (5 kg/m^2), pendimethalin 30 EC (Stomp) (0.5 kg/ha) as pre-plant incorporation, pendimethalin 30 EC (Stomp) (0.5 kg/ha) as pre-emergence, pendimethalin 38.7 CS (Stomp Xtra) (0.5 kg/ha) as pre-plant incorporation, pendimethalin 38.7 CS (Stomp Xtra) (0.5 kg/ha) as pre-emergence, oxadiargyl 6 EC (Raft) (75 g/ha) as pre-emergence, quizalfop-p-ethyl 5 EC (Targa super) (37.5 g/ha) as post-emergence, fenoxaprop-p-ethyl 10 EC (Puma super) (0.5 kg/ha) as post-emergence and weed free condition.

Among monocot weeds, *Eleusine indica* L., *Cynodon dactylon* L., *Digitaria sanguinalis* L. and *Chloris barbata* L. were dominant weeds. *Phyllanthus niruri* L., *Amaranthus viridis* L., *Euphorbia hirta* L., *Heliotropium indicum* L., *Gynandropsis pentaphylla* L., *Launaea nudicaulis* L. and *Oldenlandia umbellata* L. were found as major weeds among dicot weeds. *Cyperus rotundus* L. was the only sedge found associated with bidi tobacco nursery.

At 30 DAS, pre plant incorporation of pendimethalin 38.7 CS at 0.5 kg/ha recorded significantly the lowest dry weight of weed biomass. At 45 and 55 DAS, weed free condition recorded significant reduction in dry weight of total weed biomass. Pre plant incorporation of pendimethalin 38.7 CS at 0.5 kg/ha registered higher weed control index as it controlled monocot, dicot weeds and sedges effectively at 30 DAS. At 45 DAS and 55 DAS the maximum weed control index was observed under weed free condition.

Among different weed management practices, weed free condition proved to be significantly superior in recording plant stand, root length and shoot length of seedling, dry matter accumulation as well as the highest number of transplantable seedlings and benefit: cost ratio also. Application of pendimethalin 38.7 CS (Stomp Xtra) at 0.5 kg/ha as pre-plant incorporation was also found superior among herbicidal treatments for improving growth and yield attributing characters of bidi tobacco nursery.

Effect of chemical herbicides on weed management and performance of spring planted sugarcane in Gangetic alluvium of eastern India

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Sugarcane, a principal crop in West Bengal delta is predominantly a rainfed crop and is seriously affected by weeds in cane yields. Weeding operations in sugarcane involves considerable overhead. The composition of weed flora in the crop is changing. India has been known as the original home of Sugarcane and sugar. Weed management is a major problem in successful cultivation of the crop. A field experiment was conducted at the Instructional Farm of Bidhan Chandra Krishi Viswavidyalaya, West Bengal, to study the crop performance and weed flora as affected by different weed management measures on spring planted sugarcane.

The experiment was laid out in Randomized Block Design (RBD) with 3 replications and 10 treatments combinations *i.e.*, Untreated control, ametryne at 1.5 kg/ha at 30 DAP followed by hand weeding at 45 DAP, ametryne at 3.0 kg/ha at 30 DAP, ametryne at 1.0 kg/ha at 30 DAP followed by 2, 4-D at 1.0 kg/ha at 60 DAP, atrazine at 1.0 kg/ha at 30 DAP followed by 2, 4-D at 1.0 kg/ha at 60 DAP, hand weeding twice at 30 and 60 DAP, atrazine at 1.0 kg/ha at 30 DAP, 2, 4-D at 1.0 kg/ha at 30 DAP, atrazine at 1.0 kg/ha at 30 DAP followed by Glyphosate at 1.0 kg/ha at 60 DAP and 3 hand weedings at 30, 60 and 90 DAP, respectively. Observations on five plants average basis for crop performance and for weed flora as well as weed biomass production were recorded from the experiment. Soil of the experimental site was sandy loam in texture, low in organic carbon and medium in available phosphorus and potassium content. The RDF based application of plant nutrients was taken in practice.

Ametryne at 1.0 kg/ha at 30 DAP followed by 2, 4-D at 1.0 kg/ha at 60 DAP was most effective treatment in respect of suppression of all types of weeds, their density and biomass at all the growth stages and nutrient depletion by weeds in sugarcane field. Application of ametryne at 1.0 kg/ha at 30 DAP followed by 2, 4-D at 1.0 kg/ha at 60 DAP in spring planted sugarcane effectively improved growth, yield attributes as well as yield of sugarcane. Three hand weedings at 30, 60 and 90 DAP was the next best treatment. Maximum gross return, net return and B: C ratio was observed under ametryne at 1.0 kg/ha at 30 DAP followed by 2, 4-D at 1.0 kg/ha at 60 DAP and emerged out to be the best weed control treatment in terms of economics.

Field evaluation of interculture-cum-fertilizer applicator in cotton crop

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Interculture is a most important operation in increasing agricultural productivity and profitability. It includes soil loosening, weeding, fertilizing, and ridge forming between rows. Cotton (*Gossypium* spp.) is one of the important crops of India with total annual production of 37.7 million bales from 12.2 million hectares with a productivity of 524 kg lint/ha. It is grown in *Kharif* season and its long duration crop, weed infestation is quite high and results in reduced cotton yield. In cotton crop, normally 2-3 weedings are required. Weeding in cotton is a very costly, laborious and a time consuming operation. Weeds have the potential to reduce the cotton production by more than 35%; together with insect-pests and disease pathogens, these can cause a yield loss of more than 80% in this crop. Weeding alone takes 30-35% of cost of cultivation in cotton production thereby reduces profit. Moreover, doses of fertilizer in three splits, *viz*. 100:50:50, 160:80:80 and 240:120:120 are recommended for healthy growth of plant. Also, site specific application with metered quantity of urea helps in enhancing utilization efficiency, saving in input cost and reduced environmental degradation due to excessive use of fertilizer. For designing fertilizer delivery system, bending resistance of cotton stem was measured as 86 g at 6 leaves stage (25 DAS) and 414 g at 10 leaves stage (45 DAS), which is the most critical parameter for mechanical actuation of fertilizer delivery system. Physical properties of granular urea measured, *viz*. bulk density, number of grains in one flute and mean grain diameter were 0.760 g/cm^3, 50 and 3.38 mm, respectively. Fertilizer delivery system consist of actuating striking arm, which is provided with bearings at two extreme ends and tension spring which opens at 68.8 gm force at leverage arm of 17 cm. Based on the above design requirements, a self-propelled interculture-cum-fertilizer applicator has been developed at ICAR-CIAE, Bhopal for spaced crop. It consists of main frame, 5 hp diesel engine, two fertilizer boxes (each of capacities 8 kg), fluted roller metering mechanism, triggering mechanism to detect plant and deliver fertilizer to target plant and sweeps provided for weeding operation. The prototype has been evaluated in cotton crop (planted at 90 x 60 cm) at 45 DAS for weeding and urea spot application. The soil moisture content was between 16-18%. The average plant height, crown diameter and plant stem diameter measured were 35, 46, and 0.65 cm. The average weed density was 42 no./m^2. The prototype was operated at forward speed of 1.38 km/h and at depth of 40 mm. The average weeding efficiency of the prototype was found to be 74%. The urea delivery from the plant was observed to be 7.5±2.5 cm at delivery rate of 172 kg/ha. The observed average field capacity and field efficiency were 0.12 ha/h and 52.5% respectively.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Integrated weed management in cotton

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Cotton (*Gossypium hirsutum* L.) is an important commercial crop of India is being grown in 9.5 million hectares in India which constitutes 27% of world's area under cotton cultivation with a production of 25.9 million bales. Yield level of this crop keeps fluctuating depending upon the problem of weeds, pest and diseases that are closely associated with the climatic conditions in the region. Since, the crop has long growth cycle; it has to pass through frequent rains. Among the agronomic constraints of cotton production, weed infestation has been a major issue. Losses caused by weeds in cotton ranges from 50-85% depending upon the nature and intensity of weeds. Weeds primarily compete for nutrients, moisture and sunlight during the early crop growth period than at later stage. The critical period of weed competition in cotton is 15-60 days after sowing. Any weed management systems should be economical and sustainable, reduce weed seed bank in soil, prevent weed resistance and neither injure cotton nor reduce quantity of lint yield. To be successful, under different weed management systems, timely execution of operations is very important. Any delay in timely operations of different weed control treatments or inappropriate dosage of application of herbicides reduces control of weeds, and a higher herbicide use rate causes huge herbicide costs. Hence, with this background, a study was carried out to find out bio-efficiency of combination of herbicides to control complex weed flora in cotton.

A field experiment was conducted during *Kharif* 2014 and 2015 at Main Agriculture Research Station, Hebbal, Bengaluru, to study the effect of various weed management practices on weed density, weed dry weight, yield and economics of cotton. The experiment consists of ten treatments replicated thrice in Randomized Complete Block Design. The major weeds associated with crops in the experimental field were *Cyperus rotundus, Digitaria marginata, Dactyloctenium aegyptium* (among sedges), *Echinochloa crusgalli, Cynodon dactylon* (among grasses), whereas, among broad-leaved weeds, major were *Spilanthus acmella, Ageratum conyzoides, Alternanthera sessilis, Acanthospermum hispidum, Borreria articularis, Euphorbia hirta, Commelina benghalensis.*

Among the various treatments, pre-emergence application of pendimethalin *fb* 2 hand weeding at 20 and 50 DAS recorded significantly highest kapas yield (1.46 t/ha in 2014 and 1.49 t/ha in 2015) compared to all other treatments and was found on par with pyrithiobac-sodium + quizalofop-p-ethyl *fb* directed spray of glyphosate (1.12 t/ha in 2014 and 1.28 t/ha in 2015) and pendimethalin *fb* pyrithiobac-sodium + quizalofop-p-ethyl (1.03 and 1.38 t/ha in 2014 and 2015, respectively). Similar trend was observed in other parameters. Whereas, pre-emergence application of pendimethalin *fb* pyrithiobac-sodium + quizalofop-p-ethyl recorded higher B: C ratio (4.0 and 3.8). Hence, weed management using better herbicide combination are much cheaper compared to hand weeding and mechanical weeding.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Influence of different herbicides on forage yield and quality of oats

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India has a huge population of live stock and stands first in milk production in the world but the productivity per animal is far below compared to the developed countries. The inadequate nutrition is the one of the factors responsible for low animal productivity. Feed and fodders account for about 50-75% of the total production cost of milk, meat, wool *etc.* Green fodder is the cheapest source for feeding the dairy animals and good quality fodder is must to improve the animal production and productivity. However, the availability of green fodder is grossly inadequate in the country. In India, due to increased population pressure and competing demand of food crops, it is not possible to increase the area under fodder crops. Therefore, it is highly essential to increase the fodder production per unit area. In Punjab, area under fodder crops was about 8.95 lakh ha with annual production of 730 lakh tonnes of green fodder during 2016-17. For the current livestock population of the state (82.2 lakh), available fodder supply of about 26 kg per animal per day is inadequate and far less than the required quantity of 40 kg per animal per day. Oats (*Avena sativa* L.) is an important cereal fodder crop providing nutritious fodder to the live stock. Among fodders, oats comes second after berseem from nutritional point. It was grown on 1.04 lakh ha in Punjab during 2016-17. Weeds are one of the biotic stresses which can cause significant reduction in the green fodder yield of oats. Although intercultural in fodder oats is generally not necessary but the growth of weeds must be checked in the early stages of the crop. A field experiment was carried out during Rabi 2017-18 at Forage Research Farm, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana situated in Trans-Gangetic Agro-Climatic Zone and represents the Indo-Gangetic Alluvial Plains. The objective was to study the effect of different herbicides on weed dynamics, fodder yield and quality of oats. The experiment was conducted in randomized block design having eight weed control treatments with three replications. Pre-emergence (PRE) application of pendimethalin 380, 560 and 750 g/ha was compared with post-emergence (POE) application of metsulfuron-methyl 3, 4 and 5 g/ha. Weed free and weedy treatments were also kept for comparison. The crop was infested with grassy, broadleaf weeds and sedges. Weed samples were collected by random placing of 50 x 50 cm quadrate in each plot from three places in each treatment plot and weed population was recorded at the time of first cutting. PRE pendimethalin at all three doses effectively controlled weeds as compared to POE metsulfuron-methyl. PRE pendimethalin and weed free treatments recorded highest green fodder yield among all weed control treatments whereas lowest green fodder yield was observed in weedy plots. The quality analysis revealed that there was non-significant effect of herbicide treatments on crude protein content.

Studies on bioefficacy of imidazolinone herbicides in black gram and their residual effect on succeeding pearl millet and sorghum crops

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Black gram has slow growth in its initial stages thus it faces severe competition from weeds resulting in yield reduction up to an extent of 30-50%. Major weed species infesting black gram are *Echinochloa colona, Dactyloctenium aegyptium, Eleusine indica, Digitaria sanguinalis, Celosia argentea, Phyllanthus niruri, Cleome viscosa, Cyperus rotundus* and *C. iria* whereas, during the summer season *E. colonum, D. aegyptium, Physalis minima, Portulaca quadrifida* and *C. rotundus* infested black gram field. An initial period of 20-40 days is very critical from weed competition point of view. Although pre-emergence use of pendimethalin at 1.0 kg/ha has been found effective to control weeds in green gram but a residual herbicide is needed to control second flush of weeds emerging after rains. Early post-emergence application of imazethapyr at 40-75 g/ha proved to be very effective herbicide in blackgram replacing pendimethalin across the zones.

Keeping in view the above fact, the present investigation entitled "Studies on bioefficacy of imidazolinone herbicides in black gram and their residual effect on succeeding pearl millet and sorghum crops" was studied at Research farm of Department of Agronomy, CCSHAU, Hisar during summer and *Kharif* 2017. Major weed species infesting the experimental field were *Dactyloctenium aegyptium* (37%), *Trianthema portulacastrum* (34%), *Cyperus rotundus* (21%) and *Digera arvensis* (8%) at 30 DAS. Both at 30 and 60 DAS, PRE application of imazethapyr + pendimethalin (RM) at 1000 g/ha provided 100% control of *Dactyloctenium aegyptium* and *Trianthema portulacastrum*. Among the herbicidal treatments at 30 DAS, PRE application of imazethapyr + pendimethalin (RM) at 1000 g/ha provided 90% control of weeds while at 60 DAS, 3-4 leaf stage application of imazethapyr + imazamox at 70 g/ha provided highest weed control efficiency (88%). Application of imazethapyr at 3-4 leaf stage and its ready mix combination with imazamox at 70 and 80 g/ha caused 16-30% phyto-toxicity in forms of chlorosis and stunting of black gram which disappeared within two weeks after application but suppressed the yield and yield attributes of black gram. Maximum seed yield (912 kg/ha) and yield attributes of black gram were obtained in weed free treatment which was statistically at par with two hoeings done at 20 and 40 DAS (895 kg/ha) and PRE application of imazethapyr + pendimethalin (RM) at 1000 g/ha (878 kg/ha). All herbicide treatments employed in black gram, irrespective of their dose and application time did not show any residual carryover effect on succeeding pearl millet and sorghum crops because of rapid microbial degradation of herbicides due to three flood irrigation applied to black gram and occurrence of 341 mm of rainfall between the time of application and sowing of succeeding pearl millet and sorghum crops.

Leaching Potential of Pyrithiobac Sodium in Red and Black Soils

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Pyrithiobac sodium is a selective (ALS inhibiting) post-emergence herbicide used in cotton for control of broad-leaf weeds and it is often used in combination with "fop" herbicides for broad spectrum weed control. Laboratory experiment was conducted to assess the leaching potential of pyrithiobac sodium, in red and black cotton growing soils of Telangana state in India, using the GUS index (Ground water Ubiquity Score) by estimating the sorption and dissipation characteristics of the herbicide. Red and black soil samples were collected from cotton growing farmer's fields. Adsorption of pyrithiobac sodium was estimated using the batch equilibrium protocol and dissipation was assessed at two different moisture contents of soil at a constant temperature under controlled conditions.

Freundlich equation was used to determine the adsorption of herbicides on soil, where the fraction of adsorbed herbicide is low. The values of 1/n suggested the existence of non-linear adsorption. There could be a decrease in available sites as the adsorption increases. This is particularly true in soils with low organic matter and clay content. Adsorption was not linear (1/n <1) and the shape of the isotherms showed that adsorption decreased at higher concentrations which could be explained by a decrease in affinity of adsorption sites or competition with water molecules for the same adsorption sites.

The Freundlich constants K_f values for the red soil was 0.260 and for the black soil 0.542. K_d (soil-water quotient) and K_{doc} (soil organic carbon- water quotient) values for the red and black soils were 0.17 and 39.41; 0.38 and 71.45 respectively. The lower K_d/K_{df} values indicate lower sorption tendency of pyrithiobac sodium. Lower K_{doc} value in case of red soil (39.4) and higher K_{doc} value in black soils (71.45) indicate the higher affinity of the pyrithiobac sodium towards organic matter and clay-humus complexes, which are more readily formed in black soils due to the presence higher amount of clay and high-active (smectitic) clay compared to the red soils.

DT_{50} (dissipation time for 50 percent dissipation) calculated for the red soil at field capacity was 46.2 days and at 50% field capacity was 49.5 days, where as in black soil the persistence half-life was 53.30 days in case of both moisture levels (field capacity and 50% field capacity). Prolonged half life of pyrithiobac in experimental conditions reveals the herbicide's carryover capacity and probability for damage to crop grown in rotational sequence.

GUS index calculated for the red and black soils, using the DT_{50} and soil organic carbon- water quotient, 3.84 and 3.02 respectively. High GUS (>2.8) score indicates high mobility in soils and hence high potential for groundwater contamination, especially in coarse textured soils.

Dissipation kinetics and residues of pendmethalin in soil, straw and grain of rainy season mungbean

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Weeds are major constraints in getting maximum yield potentials of pulse crops. In India, yield losses due to weeds are being roughly estimated as 32-35% in crops such as cereals, pulses and oilseeds. Especially, in rainy season pulse crops, weed control is a great challenge to farmers because these crops are slow to establish and produce limited vegetative growth therefore, are not very effective competitors with weeds. Generally, in earlier days hand weeding was only remained a practice to remove weeds from pulse crops but in present scenario that too become a very difficult task because of the scarcity of labor and the rise in cost of labor. Therefore, it is necessary to rely on herbicides for an effective and timely weed control. In this respect, pendimethalin [N- (1-ethylpropyl)-3, 4 dimethyl 2, 6 dinitrobenze-namine], is being utilized extensively for control of a majority of grasses and broad-leaf weeds in various pulse crops. Though the pendmethalin is reported to possess for their moderate in persistence and relatively immobile properties (Tsiropoulos and Miliadis 1998 and Triantafyllidis *et al.* 2009) even though few report have been published about persistence of pendimethalin in soils in various field experiments (Kulshrestha *et al.* 2006). The information on its residue and degradation pattern in pulse cropping system is also lacking in literature. Therefore, an experiment was undertaken at IIPR Kanpur research farm for consecutive three years from 2014-2017 to determine its terminal residues and degradation pattern in soil, mungbean grain, and straw by following the post-emergence application of the herbicide to mungbean crop in field and pots. Pendimethalin was applied at its recommended dose of 1000 g/ha, as a post-emergence (21 days after sowing). In field experiments, the residues of the herbicide in soil were found far below to its prescribed MRL value (0.1 mg/g). The residue of herbicide in field soil was found 0.091, 0.079, 0.078, 0.065, 0.057 and 0.053 mg/g of soil respectively at intervals of 2hr, 5th, 15th, 25th, 35th, and 45th days of herbicide spray whereas, in pots it ranged between 0.079 to 0.044 mg/g of soil respectively between the time period of 2 hours to 70 days of herbicide application. The plant and grain samples were found almost free of residue. The degradation of pendimethalin in soil and in pot studies was found to operate as per first order kinetic equation, *viz*. [dMi/Dt=K ($M_á$-M_i)]. Based on residue data obtained in both of the experiments i e field and pots, it was observed that in soil, 50% of the herbicide got dissipated within a period of 118 days of herbicide spray (calculated $T_{1/2}$ =118 days, average K = =5.82X10^{-3}) and with this rate constant value (K) a period of 393 days was calculated as 90% of herbicide decayed period.

Mitigation of herbicide residues through efficient bacterial consortia

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The enormous benefits and widespread application of herbicides has undoubtedly increased crop productivity but has also resulted in unwanted effects to the ecosystem. The herbicide residues either affect the sensitive crops or shows phyto-toxic effect to the succeeding crops and thus may reduce the productivity. The residual herbicide activity, is also described in terms of half life ($T_{1/2}$) that varies with herbicides and ranges from 4 days (Sevage and Jordan 1980) to 563 days (Walker and Bond 1977). Microbes play an important role in counteracting the residual effect of herbicides. In cognizance to the above, a study was undertaken to evaluate the effect of bacterial consortium on herbicide residue in terms of rate of degradation and their half lives in soil. Five numbers of bacterial isolates consortia isolated from different locations of Assam, *viz.* the isolates from oil fields (C_1), coal fields (C_2), brick fields (C_3),paper industry (C_4), cement industry (C_5) along with a control without bacterial consortia (C_0) were evaluated for their herbicides residue degradation ability. The soils under study was sandy loam in texture with CEC - 6.28 c mol ($p^{+)}$/kg, Organic Carbon - 0.92%, available N-260 kg/ha, available P_2O_5 - 19 kg/ha, available K_20 - 86 kg/ha. The recommended rate of application of metribuzine was 500 g/ha and quizalofop-ethyl was 50 g/ha. The herbicides were applied to the soil at recommended and double the recommended dose. Bacterial consortia at 10 ml per 6 kg soil was also applied to the pots as per treatments. The cfu of the bacterial consortia were in the range of (78.33 - 114.64) x 10^{-6}/ml aliquot. Soil samples were collected periodically from the day of herbicide application (within 4 hours of herbicide application) till 30 days after application (DAA) of herbicides, processed and stored in polythene bags for analysis of various physico - chemical parameters and herbicide residue by following standard protocols. The limit of detection (LOD) and the limit of quantification (LOQ) for metribuzine and quizalofop-ethyl were recorded as 0.003 mg/kg and 0.01 mg/kg respectively.

The degradation of metribuzine and quizalofop - ethyl in soil followed a first order kinetic. The $T_{1/2}$ of herbicides in uninoculated soil was shorter than the inoculated soil with single and double doses. In this study, the $T_{1/2}$ of metribuzine and quizalofop-ethyl at double doses were shorter over the single doses of the herbicides. It can probably be explained by the microorganisms' adaptability to the double the herbicides doses. It is also evident from degradation pattern that the single herbicide doses degraded slower at the beginning of the experiment (during the first 15 days of the experiment) than the doubled the herbicide dose. From the study it was observed that the bacterial consortia isolated from oil field and coal field with longer $T_{1/2}$ recorded as the most efficient one to mitigate herbicide residues in soil.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Soil microbial population in response to applied herbicides in greengram

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Application of herbicides leads to unseen fluctuations in microbial population present in soil which can disturb their ecological balance. This paper focuses on the fluctuation of different kinds of microbial population with time due to application of pre and post emergence herbicides in greengram. The study included estimation of population of total heterotrophic bacteria, fungi, actinomycetes, symbiotic nitrogen fixing bacteria and free living nitrogen fixing bacteria in soil as affected by different herbicidal treatments. Almost all the herbicides treated plots brought the microbial load down after 16 DAS. But application of oxyfluorfen instead of negatively affecting the microbial population, raised it even more than that of control where no herbicidal treatment was done except in case for actinomycetes and symbiotic nitrogen fixing bacteria. Also a sharp fall of microbial load was seen when the dose of herbicide was increased. This indicates the negative impact of herbicides on soil microflora which can in turn affect the soil health and sustainability of production system.

It was found that the microbial population (MP) was significantly different among the treatments due to different modes of action of the herbicides and their doses taken. The general trend in all the treatments including the control was that the microbial load (ML) increased with time, reaching a peak at 14-20 DAS and then decreased gradually till harvest of the crop (while in some cases there was a sharp fall). This might be due to the reason that with the rapid increase in biomass of the crop with time the MP also increased owing to the increased root exudation and biomass production of the crop and hence, the availability organic matter content and carbon and energy sources for microbial growth. While in later stages of crop where the rate of biomass production decreased, the MP also declined which might be due to increased competition among microbes for food and energy. Thus, it is expected that nutrient release would also have increased in early stages of crop. But due to application of pre-emergence herbicides, the ML started declining after 16DAS although the crop biomass kept increasing. This was found in all the treatments indicating the death of microbes due to herbicide molecules.

Application of herbicides negatively affects the microbial population of soil challenging the maintenance of ecological balance and soil health. Some molecules like oxyfluorfen have phytotonic effects to some extent while rest of the herbicidal treatments reduced the microbial load. This means that the rate of nutrient release in soil will also be retarded due to microbial deaths. In case of pulses like greengram the death of nitrogen fixing bacteria can lead to yield reduction. Thus, new ways to manage weeds must be carved out which can reduce reliance on chemicals and be nature friendly.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Mitigation measures for atrazine in soil under maize

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A pot culture experiment was conducted to assess the effect of organics and microbes in mitigating atrazine in soil. The experiment was carried out during 2017-18 at Tamil Nadu Agricultural University, Coimbatore with the test crop of maize. Soil samples were collected from the field which did not receive the atrazine previously and used for conducting the pot study. About 10 kg soil was filled up in each pot. The soil used for the study is calcareous sandy clay loam in texture having pH 8.28, EC 1.2 dS/m, OC 0.46%, available N, P, K of 145.6, 17.8 and 621 kg/ha. The treatments constituted application of FYM, green manure, crop residues, biochar, urea and microbes, *viz. Tricoderma, Pseudomonas, phosphorbacteria* and VAM along with control. The treatments were imposed 3 days before sowing of maize. Atrazine was applied to each pot equivalent to 0.5 kg/ha on 3rd day after sowing maize. Soil samples were collected from a depth of 0-15 cm on 0, 1, 3, 5, 10, 15, 30 and 45 DAA and analysed for atrazine residues. A valid homogenized representative soil sample from each replication of each treatment was taken and the atrazine was extracted using solvent mixture consisting methanol: water (7:3). The soil-suspension was centrifuged and the supernatant was filtered. The above step was repeated two times and the supernatant phase was combined and concentrated to dryness. The residues of atrazine were dissolved in HPLC grade acetonitrile and determined by HPLC equipped with Photo Diode Array Detector at a wave length of 221 nm. The initial deposition on day 0 (After 1 hour) ranged from to 0.423 - 0.721 mg/kg across different treatments sources consisting of cultural and microbes application to enhance the degradation of atrazine from the soil. The degradation equation, correlation coefficient and half lives were worked out. The results revealed that the dissipation was faster under FYM, vermicompost and biochar applied treatments and the slowest degradation was noticed in control. The lowest half life of 8.8 days was observed in FYM treatment. The dissipation of atrazine in soil followed first order reaction kinetics irrespective of sources of mitigation measures and about 80% of the initial atrazine deposition degraded from the soil on 45th day after its application. Based on the present results it was found that the FYM at 10 t/ha or vermicompost at 5/ha or biochar at 5 t/ha is efficient in reducing the residual concentration of atrazine in maize grown soil. This could be due to the enhanced adsorption of the compounds by these sources. The application of FYM degraded the atrazine very fast with the half life 8.8 days and slow degradation by microbes could be ascribed to the low quantity of application when compared to FYM.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Residual phytotoxicity effects of different integrated herbicides management in soils from field-treated plots and post-harvest field

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A field experiment was carried out to determine the integration of different herbicides on fiber quality traits of cotton at Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat) during *Kharif* 2013-14 and 2014-15. The trial was conducted in a randomized complete block design and replicated thrice. Each plot consisted of five rows (6.0 m long) with 0.45 m distance between rows. Herbicides are used quite extensively in agricultural production system throughout the world, and India is no exception to this. Herbicides, when applied to the field do not only control targeted weeds, but may also leave unwanted residues in the soil, which are ecologically harmful. Although the efficacy of herbicide in controlling weeds is important, its residual impact should also be considered for environmental safety. Preferred herbicides should not only have good efficacy, but also poses minimum adverse effects to crop, ecology and environment. Bioassay and chromatography are among the several methods commonly used to determine pesticide residues in soil. Bioassay for residual phytotoxicity has been used to investigate many practical aspects of herbicide behavior in the environment for long time (Horowitz 1976). It is a practical qualitative or semi-quantitative method of analysis, whereby the residues, which really affect plant development, are determined. Commonly, seed germination and seedling performance are used to investigate the residual phytotoxicity (Nyffeler *et al.* 1982; Sunderland *et al.* 1991). The residual phytotoxicity effects can detect the herbicide or chemical residue present in the soil at concentrations high enough to adversely affect crop growth, yield and quality (Pestemer *et al.* 1980). Depending on the type and concentration of the residues, injury symptoms usually appear within 10 to 20 days after seedling emergence. Cucumber, sorghum, corn and oat are the common plant species used in bioassay studies (Horowitz 1976), because they are easy to grow and have marked sensitivity to many herbicides. Present study reports residual phytotoxicity effects of seven commonly used narrow and broad spectrum herbicides.

Soil residual phytotoxicity of commonly used herbicides in cotton crop in India were investigated through bioassay. Pendimethalin at 900 g/ha, oxyfluorfen at 180 g/ha, oxadiargyl at 90 g/ha, quizalofop-ethyl at 40 g/ha, imazethapyr at 75 g/ha, propaquizafop at 50 g/ha and glyphosate at 960 g/ha were applied to field plots of 6.0 x 6.0 m^2. Sorghum and cucumber were used in the bioassay and succeeding crops groundnut, green gram and pearl millet to test the residual effect of herbicides in the soil of the treated plots and post-harvest field. Soil, sampled at 30 day after treatment (DAT) for pre-emergence herbicide and until 2 weeks (WAT) for post-emergence herbicide later, show significant affect the seed germination and seedling development stage of sorghum and cucumber. There was no residual toxicity of pre and post-emergence herbicides as observed through field bioassay after harvesting cotton crop and it was found safe to grow groundnut, green gram and pearl millet as succeeding crop.

Fate of metsulfuron-methyl and and clodinafop propargyl in wheat

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Wheat (*Triticum aestivum* L.) is the most important cereal crop, anintegral component of the food security system. Wheat crop is infested with heavy population of *Phalaris minor*, *Cyperus rotundus, Cynodon dactylon, Chenopodium album, Anagallis arvensis, Avena fatua, Convolvulus arvensis* and *Lathyrus aphaca etc.* Combination mix herbicides are very popular with the farmers due to theirhigh potency at lower doses to kill grassy along with broad-leaved weeds have been developed. Keeping all these facts in view, the present investigation was carried out to evaluate the persistence and behavior of combination mix herbicides in wheat crop and soils. Metsulfuron-methyl, [methyl 2- (4-methoxy-6-methyl-1, 3, 5-triazine-2-ylcarbamoylsulfamoyl) benzoate], a popular sulfonylurea herbicides, is widely used due to its selectivity against a wide range of weeds in cereal, pasture, and plantation crops. It is used alone or as a mixture to control broad-leaf weeds in cereal crops. Clodinafop-propargyl, (prop-2-ynyl (2R)-2-[4- (5-chloro-3-fluoropyridin-2-yl) oxyphenoxy] propanoate) a post-emergence herbicide, is being used largely to control weeds in wheat in India. A ready mix combination product of metsulfuron methy and clodinafop propargyl was evaluated on wheat cropfor its residues in the wheat foliage, grains and soil. A field trial was conducted in the IARI field on wheat, variety HD 2328. A combination mix of the herbicide UPH-206 (metsulfuron-methy + clodinafop propargyl) was applied 35 days after transplanting the wheat crop at 400 and 800 mL formulataion/ha, and 2^{nd} spary was applied again after 15 days. The samples of wheat foliage and soil were collected periodically at 0, 1, 3, 7, 10 and 15 days after 2nd spray and grains at harvest time. The samples of wheat foliage, soil and grains were processed by AOAC Official Method 2007.01Qu ChERS method. The samples were analysed by Hitachi HPLC model 7400 - with UV-Vis detector at l_{max} 242 nm. Metsulfuron-methyl and clodinafop propargyl eluted at2.42 and 4.62 min, respectively. The LOD for metsulfuron and clodinafop was 0.005 and 0.01 mg/mL and LOQ in wheat foliage, rice grains and soil was 0.01 and 0.05 mg/kg for metsulfuron-methyl and clodinafop propargyl, respectively. The initial residues of metsulfuron-methyl on wheat foliage were 2.22 mg/kg which dissipated with time by day 7. The residues in double dose of application were 3.49 mg/kg, dissipated to 0.54 mg/kg by day 15. The half life recorded on wheat crop was 3 days. Clodinafop propargyl residues on wheat foliage were 0.26 mg/kg which dissipated to 0.11 mg/kg by day 3. In the double dose of application initial residues recorded was 0.37 which persisted till day 5. The half life of clodinafop propargyl was 2.3-3.3 days at recommended and double dose of application. The residues of metsulfuron-methyl and clodinafop propargyl in harvest time grains were below the detectable limit, of 0.01 and 0.05 mg/kg for metsulfuron-methyl and clodinafop propargyl, respectively.

Simultaneous determination of 146 multiclass pesticides in soil by LC-MS/MS

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Soil is the ultimate sink for pesticides which are used in agriculture for crop protection. A major part of pesticide used in agricultural fields passes into soil by missing their intended target. Further, contamination in soil takes place by spray drift, surface and subsurface runoff and spillage during application. Pesticide residues in soil pollute groundwater aquifers through leaching and affect quality of agricultural crops and human health.

Recently, neonicotinoids and fipronil, have been blamed for disturbing environmental balance. In 2018, tricylazole contamination in soil endangered Rs. 22,000 crore Basmati rice export to EU. This scenario compels us to realize that non-judicious use of persistent pesticides resulting their accumulation in the soil and subsequent crop grown in such soil may contain high levels of undesired pesticide residues, even without application of the same and ultimately result into export rejections and safety barriers. In India, no systematic study for pesticide contamination in soil has been conducted. Most of the studies are confined to the residues of highly persistent organochlorines. The contamination status of currently used and registered pesticides is unavailable. Almost all the literature reported studies are conducted using GC-ECD and without confirmation by Mass spectroscopy. In the present investigation, a multi-residue method based on QuEChERS with LC-MS/MS quantification has been developed for trace level analysis of 146 LC amenable pesticides in soil.

Instrumenal parameters like mobile phase composition, flow rate, qualifier and quantifier ion, collision energy *etc.* were optimised for each of the 146 pesticides, consisting of 74 insecticides, 30 fungicides and 42 herbicides, under Electrospray Ionization (ESI) in +/- mode using Shimadzu LCMS/MS-8030 equipped with Zorbax Eclipse Plus C-18 column.

For optimization of the extraction and cleanup method dry and hydrated soil (5 g) were taken seperately, treated with anhydrous magnesium sulphate (2 g), sodium chloride (0.5 g), disodium hydrogen citrate (0.25 g) and trisodium citrate (dihydrate) (0.5 g) in acetonitrile and subsequently after vorting and centrifugation, the supernatent (1 ml) was subjected to sample cleanup using diffrenent proprotion of C-18 and PSA in presence of anhydrous magnesium sulfate (150 mg). It was observed equal amount of C-18 (50 mg) and PSA (50 mg) in both dry and hydrated soil were not able to offer requisite cleanup for the pesticide where only 22.6% and 45.9% of pesticides were recovered in acceptable range of 70-120% at 0.01 µg/g fortification level. On the contrary PSA (100 mg) alone was capable to achieve satisfactory cleanup where 77.4% (113 out of 146) pesticides were recovered in accptable range with 90.4% pesticides showing accepable repeatability (RSD ≤20%) when compared agaist solvent standard. The matrix interferences, as observed with C-18 (50 mg) and PSA (50 mg) clean-up, were nullified by the use of matrix match standard and recoveries of acceptable range was obtained in 82.8% pesticides as compared to 45.9% of pesticides against solvent standard.

The developed method with mass confirmation technique for detecting and quantifying the trace level residues of 146 presently used pesticides in soil and can be used for assessing the soil health status with respect to pesticide residues and can help the farmer in planing of pesticide application schedule in next crop or deciding suitablility of growing a crop in specific location contaminated with specific pesticide, if the produce is meant for export purpose.

Impact of herbicide mixtures on enzyme activity in puddled rice soil

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Soil enzymes are the potential indicators of soil quality and health. Excessive and continuous use of herbicides without the knowledge of their effect on soil enzymes may have adverse impact on the biochemical functioning of soil. Hence, the study was undertaken with the objectives to assess the impact of herbicide mixtures on dehydrogenase, urease, protease and acid phosphatase enzyme activity in soil and also the stage of the crop at which these enzymes have the highest activity. Field experiments were conducted during *Kharif* and *Rabi* 2014-15 at farmers' fields in Kalliyoor Panchayat, Thiruvananthapuram, Kerala. The treatments comprised of bispyribac-sodium + metamifop 60, 70, 80 and 90 g/ha, penoxsulam + cyhalofop-butyl 120, 125, 130 and 135 g/ha, bispyribac-sodium 25 g/ha and penoxsulam 22.5 g/ha, hand weeding twice at 20 and 40 DAS and weedy check. The results revealed that before herbicide application, no significant difference was observed among the treatments in the enzyme activity. An increase in dehydrogenase enzyme activity was observed from seedling to booting stage and the highest activity was observed at booting stage (60 DAS) and the lowest activity at harvest stage. At 30 DAS, 60 DAS and at harvest, herbicide treated plots recorded higher dehydrogenase activity compared to hand weeding and weedy check. With regard to protease activity, a decline in the enzyme activity was observed at 30 DAS as compared to 15 DAS; the enzyme activity was found to increase at 60 DAS and again decreased at harvest stage. At all the stgaes of observation, the herbicide treated plots registered statistically comparable or higher protease activity as compared to non-herbicide treatments. The highest protease activity was recorded at seedling stage (15 DAS) and the lowest at harvest satge. Urease followed the same trend as that of protease activity. Similar to that of protease activity, all the herbicide treated plots registered comparable or higher urease enzyme activity in soil than that of non-herbicide treatmens.Seedling stage of the crop (15 DAS) recorded the highest acid phosphatase activity and was found to decrease at 30 DAS and again an increase in activity was observed at harvest. Herbicide treated plots registered higher or comparable values with that of non-herbicide treated plots at all stages of observation. The enzyme assay results indicated that, the tested herbicide mixtures *viz.*, bispyribac sodium + metamifop and penoxsulam + cyhalofop-butyl did not have any negative impact on soil enzyme activity, the soil quality indicator, implying the environmental safety of these two herbicide mixtures.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Evaluation of different post-emergence herbicides as alternative to imazethapyr for weed control in *Kharif* pulses and their residual effect on succeeding wheat and mustard crops in arid Rajasthan

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Mung bean and moth bean are the important *Kharif* pulse crops in arid and semi arid regions of Rajasthan. Being the *Kharif* crops, as well as having very slow initial growth, these crops often face heavy weed infestation. In mung bean and moth bean yield losses due to weeds infestation have been estimated to be around 50% and 75%, respectively. This warrant effective weed control as foremost management practice to boost productivity of these crops in the region. Hand weeding, the most common weed management practice followed is not only cumbersome but costly too. Hence, to save time and labour cost, post emergence herbicide like imazethapyr either alone or in combination with other herbicides is recommended for *Kharif* pulses. However, these herbicides have been reported to cause crop setback in *Kharif* crops under moisture stress and have residual toxicity on succeeding crops. Hence, the present study was undertaken during 2017-18 to identify optimum dosage of alternative herbicide as broad spectrum post-emergence weedicide for mung bean and moth bean with minimum residual toxicity on succeeding crops. In weed management treatments, weedy check and weed free were taken as absolute control, while hand weeding was taken being farmer's practice and pendimethalin as recommended pre-emergence herbicide for comparison with post emergence herbicides for weed control efficacy and economics. Among the test herbicides as post-emergence herbicides imazethapyr (50 g/ha); imazethapyr + imazamox (60 g/ha); clodinafop-propargyl + sodium-acifluorfen (187.5 g and 250 g/ha); propaquizafop + imazethapyr (100 g and 125 g/ha) were applied at 20 DAS. During *Rabi* season, mustard and wheat were raised on the same field to assess the residual toxicity of different post-emergence herbicides.

Results revealed that plant height of mung bean and moth bean was not affected significantly due to application of different herbicides, however crop injury due to herbicide, shortest plants were observed under imazethapyr application. In mung bean, propaquizafop + imazethapyr (125 g/ha) recorded highest seed yield (1095 kg/ha) and weed control efficiency (52.5%); and lowest weed density (52.3 weeds/m^2) and weed dry matter (102.5 g/m^2) at harvest. However, this treatment was statistically at par with clodinafop-propargyl + sodium-acifluorfen (250 g/ha) in terms of weed density, dry matter and grain yield. In moth bean, significantly highest crop dry matter accumulation and seed yield (969 kg/ha) was recorded in propaquizafop + imazethapyr (100 g/ha) while, imazethapyr + imazamox (60 g/ha) recorded the significantly highest weed control efficiency (58.4%) and lowest weed dry matter (69.4 g/m^2) and weed density (48.1 weeds/m^2) at harvest which was closely followed by clodinafop-propargyl + sodium-acifluorfen (250 g/ha). In succeeding mustard, under residual effect of imazethapyr; imazethapyr + imazamox and propaquizafop + imazethapyr (125 g/ha) significantly lower seedling emergence, plant population at 30 DAS, plant dry weight at 45 DAS and grain yield were recorded as compared to clodinafop-propargyl + sodium-acifluorfen. However, in wheat no significant residual effect of herbicides was noticed. It can be inferred from the study that considering the negative effects of imazethapyr containing herbicides on succeeding crops, herbicidal molecules like clodinafop-propargyl + sodium-acifluorfen (250 g/ha) can be alternative safe herbicides for *Kharif* pulses after thorough evaluation.

Dissipation studies of bispyribac sodium in paddy and its terminal residues in rice grain

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Rice is one of the major cereal crop and like other crops, it also suffers from serious weed infestation. About 33 per cent of rice production is lost in India due to weed infestation. Herbicide usage is one of the major inputs in the improvement technology for increasing crop production. Bispyribac sodium (Sodium 2, 6-bis [(4, 6-dimethoxy-2- pyrimidinyl carboxy benzoate)] is a post-emergence systemic herbicide belonging to pyrimidinyl carboxyl herbicide group. It has wide spectrum activity and effectively controls growth of many annual and perennial grasses, sedges and broad-leaved weeds in rice. It is biologically active at low application rates. The fate and environment behaviour of bispyribac sodium in soil is of concern as a few studies have shown that bispyribac residues had phytotoxicity to sensitive crops, moderate to high mobility in soil and slightly persistent in aerobic soil. The degradation of bispyribac sodium in soil is directly related to chemical aqueous hydrolysis and microbial metabolism. A field investigation consisting of four treatments *viz.* bispyribac sodium 10 g/ha, bispyribac sodium 20 g/ha, bispyribac sodium 40 g/ha and control replicated five times in a randomized block design (RBD) at Research Farm of Agronomy during *Kharif 2017* was conducted to determine dissipation behaviour in soil and terminal residues of bispyribac sodium in rice crop. Soil samples (0-15 cm depth) using a tube auger from 6-7 spots in each plot at different time intervals *i.e.* 0, 1, 3, 5, 7, 10, 15, 30, 45 and 60 days after herbicide spray and rice grain samples at the maturity of crop were collected, processed and subjected to bispyrbac sodium residue analysis by a validated HPLC method with an accepted recovery of above 80%. The quantitative determination of bispyribac sodium by concentration vs peak area showed a linearity ranging from 0.025 to 5 µg/ml. Bispyribac sodium 20 g/ha persisted in soil upto 15 days after herbicide application whereas at higher dose *i.e.* bispyribac sodium 40 g/ha, it persisted in soil upto 45 days after herbicide application. The degradation of bispyribac sodium in soil exhibited first order kinetics and the values of half-life ranged from 3.20 to 12.04 days. Bispyibac sodium residues in rice grains and rice straw at the time of harvest were below detectable levels (0.001 ìg/g) in all three treatments of herbicide application. This indicated that the bispyribac sodium did not leave any residues in rice crop at any of the applied doses. From the study, it may be concluded that post-emergence application of bispyribac sodium in rice for weed management could be considered safe, as its residues were below the prescribed MRL (0.05 mg/kg).

Evaluation of priority™ Plus 31.95 WG with Arylex™ active for post-emergence weed control in wheat in India

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Priority Plus 31.95 WG, a premix combination of Arylex™ active and Pyroxsulam, was evaluated in field trials conducted during 2016 and 2017 crop seasons in Uttar Pradesh and Madhya Pradesh provinces in India. The objective of these studies was to evaluate the bio-efficacy and crop response of Priority Plus for broad-spectrum weed control in wheat. Field study treatments included two dose rates of Priority Plus 31.95 WG (19.17 and 23.96 g/ha with Polyglycol PG 26 2 N at 750 ml/ha); Clodinafop 15% + Metsulfuron 1% (Pre mix) at 64 g/ha and Mesosulfuron 3% + Iodosulfuron 0.6% (Pre mix) at 14.4 g/ha as a standard treatments and an untreated control.

Post-emergence foliar application targeting 2 to 4 leaf stage of grass weeds (namely *Avena fatua*) was done using a backpack knapsack sprayer fitted with flood jet nozzle. Treatments were arranged in a randomised block design with four replications.

Assessment of treatments was done based on percent visual weed control at 15, 30 and 45 days after application (DAA) and weed count at 30 DAA. Crop response was also evaluated at 7, 15 and 30 DAA by visual rating based on 0-100% phytotoxicity rating scale. Priority Plus 31.95 WG at 23.96 g/ha provided effective control (85-95%) of *Avena fatua, Anagallis arvensis, Chenopodium album, Lathyrus apahaca, Rumex dentatus, Sinapis arvensis* and *Vicia sativa* at 30 DAA. Priority Plus 31.95 WG at 23.96 g/ha was either similar or better than the standard treatments against evaluated weeds. All the tested dose rates of Priority Plus were found to be safe to the wheat crop. Priority Plus 31.95 WG demonstrated efficient control of the *Avena fatua* and key broad-leaf weeds with adequate crop safety, representing a potential new effective herbicide for wheat growers in India

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Evaluation of new herbicide molecules in transplanted rice as influenced by seedling number.

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The farmers were often recommended to have not more than three seedlings per hill during transplanting. However, its impact on weed infestation scenario was still a researchable issue in temperate Kashmir, as initial period of rice growth is very slow. Keeping this under consideration, a field experiment was conducted during *Kharif*, 2016 & 2017 at the Agronomy Research Farm, Faculty of Agriculture, SKUAST–K Wadura Sopore to evaluate new herbicide molecules in transplanted rice as influenced by seedling number, apart from knowing the phyto-toxicity effect, if any. Rice Cv. Jhelum was transplanted at a common spacing of 30 x 15 cm and fertilizer level of 100 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha. The crop was transplanted on 20-06-2016 and 12-06-2017 and harvested on 25-09-2016 and 20-09-2017 in 2016 & 2017, respectively. The experiment was laid out in Randomized Block Design and the data on weeds' density and dry weight were analyzed using transformation of square root of (X + 1). The three seedling transplanted resulted more registration of panicles/ m^2 and grain and straw yield and was significantly superior over 02, 04 and 05 number of seedlings/hill. However 03 and 04 number of seedling per hill were at par in grain yield (Table 2). Among the weed management practices all herbicide treatments along with weed free were significantly superior over weedy check in registration of panicles/m^2 and yield (Both grain and straw). Among all the chemical management practices the treatment bispyribac-sodium+ azimusulfuron (25 g + 17.5g/ha 15 DAT) was significantly superior in yield and yield attributes. However in case if straw yield it was found at par with weed free. The higher doze of herbicide combinations result in reduction of panicles/m^2 and consequently grain and straw yield. This might be due to phytotoxicity of higher dosage. Finally it was concluded that seedling number, 03 number seedling/hill were significantly superior in registration of yield and yield attributes. Similarly among weed management practices, bispyribac-sodium+ azimusulfuron (25 g +17.5g/ha 15 DAT) were better in controlling weeds and getting higher paddy grain yields.

Response of diquat on garden pea and associated weeds

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Garden pea crop has recently gained popularity among farming community for its use as grain as well as vegetable purpose. However, various production obstacles thwart its productivity and major one is weed problem. Frequent irrigations, wider spacing especially in regions of high fertility makes this crop a suitable candidate for weed infestation. Initial period *i.e.* 30-60 days is critical for weed competition, beyond that crop smothers weeds owing to good canopy coverage. Weeds can be controlled principally by manual, mechanical and chemical means and each method has its share of pros and cons. Manual labour is becoming scarce and costly these days while mechanical method causes root injury to the crop. Chemical control seems most conducive to farmers due to its practicality. Various pre-plant incorporated and pre-emergence herbicides along with some post-emergence herbicides have been tested and recommended under different agro-climatic conditions for garden pea. In the present investigation garden pea variety 'Arkel' was sown in *Rabi* season of 2015-16 and 2016-17 with standard recommended package of practices except weed control for garden pea. Treatments included application of a pre plant incorporation herbicide diquat 20% SL (0.5, 0.6, 1.2, and 2.4 L/ha) with spray volume of 400 L/ha. Application of paraquat dichloride 24% SL (0.5 L/ha) was also taken as standard check. Two hand weedings and weedy check plots were also kept for comparison.

In the experimental field *Phalaris minor* and *Polypogon* spp were major grassy weed species while *Chenopodium album*, *Coronopus didymus*, *Medicago denticulata*, *Melilotus indica*, *Fumaria parviflora*, *Polygonum plebenjum* and *Vicia sativa* were the major broad-leaved species. Weeds were more effectively killed during second year compared to first year of experimentation. During second year field was free of weeds till 7 days after application in diquat 2.4 L/ha and paraquat 0.5 L/ha treatments. While during first year crop was never devoid of weeds at any stage. During both years all the herbicidal treatments have significantly reduced density and dry weight of both grassy and non-grassy weeds. At higher doses weeds were controlled more effectively than lower doses. Among grassy weeds *P. minor* was less effectively controlled by diquat compared to *Polypogon* species. Among broad leaved species *C. album*, *F. parviflora*, *C. didymus*, *V. sativa* were completely controlled by diquat at 2.4 L/ha. *V. sativa* and *F. parviflora* were completely controlled by all the doses of diquat except 0.5 L/ha. Diquat at 2.4 L/ha recorded lowest total dry weight of weeds till 14 days after application. Highest pod yield was recorded in two hand weeding treatments. Among herbicide treatments highest pod yield was obtained in diquat 2.4 L/ha which was at par with diquat 1.2 L/ha and during both years and duing first year with paraquat 0.5 L/ha also.

No phytotoxicity was seen on crop till 30 days after application so based on these studies, it can be concluded that diquat 1.2 L/ha can be applied to garden pea crop for effective weed control and obtaining higher pod yield. However recommendation needs some more trials at different locations.

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Efficacy of halauxifen-methyl + pyroxsulam on broad spectrum weeds control in wheat

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Wheat is the one of the most produced crop on Earth, Wheat provides a large fraction of the dietary protein and total food supply, and is grown all throughout the world in a wide variety of climates. Wheat is a staple crop, grown as a primary food product and for other uses as well. Wheat is one of the most abundant sources of energy and proteins for the world population and its increased production is essential for food security (Chhokar *et al.* 2006). The presence of weeds in wheat can adversely affect its production in a number of ways. Weeds compete with crop plants for light, moisture, nutrients and space and restrict its yield potential.

Herbicides are the most accepted control measure to suppress the weeds, but chemicals need to check the ill effect on environment not only in the main crop but their effects on follow up crop. Thus, use of new and comparatively safe herbicides is one of the options left with the farmers to eliminate crop weed competition at early growth stages of crop. Among popular selective herbicides, halauxifen-methyl + pyroxsulam in wheat field has the potentiality to keep the weed bellow the economic threshold level. Thus, a field experiment was conducted to evaluate the efficacy of halauxifen-methyl + pyroxsulam for management of wide range of weed flora, weed control efficiency and yield of transplanted rice in the *Rabi* season during 2015-16 and 2016-17 at N.E. Borlaug Crop Research Center of G.B.P.U.A and T, Pantnagar. The experiment was conducted in RBD with eleven weed control treatments replicated thrice. Sulfoulfuron + metsulfuron –-methyl 80 WG (with surfactant). At 40 + 1250 g/ha was used as standard checks. All the herbicides were applied as post - emergence using 300 liters of water/ha with the help of knap sack sprayer fitted with flat fan nozzle.

The major weed flora in the experimental field were *Phalaris minor, Avena ludviciana, Chenopedium album, Coronopus didymus, Mallugo denticulata, Malwa neglecta* and *Polygonum plebejium.*

Density of *Avena ludoviciana* and *Coronopus didymus* both were totally controlled with the combination of Halauxifen-methyl + Pyroxsulam (with or without surfactant) applied at 5.21 + 18.75 g/ha at 30 DAS. Maximum grain and straw yield was achieved with combination of halauxifen-methyl + pyroxsulam with surfactant applied at 5.21 + 18.75 g/ha which was at par with its respective lower doses applied at 4.17 + 15 g/ha and also the herbicide combination has no phytotoxicity effect on rice crop as well as residual effect on succeeding maize crop.

Efficacy of XR-848 benzyl ester + penoxsulam for weed control in transplanted rice

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Rice is a major and important crop in the world, it feeds one third of the world population to whom it supplies almost two thirds of the food requirements. From an area of 42.13 million ha, India is producing about 40% of the world rice production. In rice, infestation of all types of monocot and dicot weed flora was observed. Like other cereal crops, rice also suffers severely from weed competition. The diverse weed flora under transplanted conditions (grasses, sedges and broad-leaved weeds) can cause yield reduction up to 76% **(**Singh *et al.* 2004**)**.

Herbicides are the most accepted control measure to suppress the weeds, but chemicals need to check the ill effect on environment not only in the main crop but their effects on follow up crop. Thus, use of new and comparatively safe herbicides is one of the options left with the farmers to eliminate crop weed competition at early growth stages of crop. Among popular selective herbicides, penoxsulam in rice field has the potentiality to keep the weed below the economic threshold level. Its efficacy can be improved if it combined with new herbicide molecule. Thus, a field experiment was conducted to evaluate the efficacy of XR-848 benzyl ester + penoxsulam for management of wide range of weed flora, weed control efficiency and yield of transplanted rice in the *Kharif* season of 2016 and 2017 at N.E. Borlaug Crop Research Center of G.B.P.U.A and T, Pantnagar. The experiment was conducted in RBD with ten weed control treatments replicated thrice. bispyribac-Na 10% SC 250 g/ha and penoxsulam 24% SC at 93.75 and 125 g/ha were used as standard checks. All the herbicides were applied as post-emergence using 400 liters of water/ha with the help of knap sack sprayer fitted with flat fan nozzle.

The major weed flora in the experimental field were *Echinochloa colona, Echinochloa crusgalli, leptochloa chinensis, Ischaemum rugosum, Alteranthera sessilis, Ammania baccifera, Cyperus rotundus,Cyperus difformis* and *Cyperus iria.*

Application of XR-848 benzyl ester 12.5 g/L (w/v) + penoxsulam 20 g/L OD (w/v) at 1250 and 1500 g/ha managed to achieve complete control over *Echinochloa crus-galli, Leptochloa chinensis, Alternanthera sessilis, Cyperus difformis* and *Cyperus iria.* Minimum dry biomass of weeds, maximum weed control efficiency and highest grain yield was achieved with the application of XR-848 benzyl ester 12.5 g/L (w/v) + penoxsulam 20 g/L OD (w/v) at 1500 g/ha which was followed by its lower dose (1250 g/ha). This herbicide combination has no phytotoxicity effect on rice crop as well as residual effect on succeeding wheat crop.

Halauxifen + florasulam + carfentrazone - A new herbicide mixture to manage broad-leaf weeds in wheat

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India is the second largest producer of wheat in the world producing 99.5 Mt of grains with the productivity of 3.32 t/ha from the area of 29.7 M ha. Weed infestation is one of the major bottlenecks in realizing the potential yield of wheat. Weeds are reported to causes up to 66% reduction in wheat grain yield if not timely controlled. In recent years, the broad-leaf weeds have emerged as the serious problem in the irrigated wheat ecosystem. Herbicides are the major tool to combat weed menace in the most wheat growing area of the country. Although weed control through herbicide is very effective to manage weeds, continuous use of herbicides with a similar mode of action may lead to the selection of resistant weeds biotype in wheat. Therefore, development and evaluation of new herbicide are essentially required for sustainable herbicide-based weed management in wheat. Therefore the present study was undertaken to study the effectiveness of newly developed herbicide mixture on broad-leaf weeds in wheat.

The field experiment was conducted during 2016-2017 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India. The experiment was laid out in Randomized Complete block design having eleven treatments *viz.* halauxifen-methyl ester + florasulam (40.85% WG) + polyglycol 12.76 g/ha, metsulfuron-methyl + surfactant (20 WG) 4 g/ha, carfentrazone (40 DF) 20 g/ha, 2, 4-D Na (80 WP) 500 g/ha, 2, 4-D E (38 EC) 500 g/ha, metsulfuron + carfentrazone + surfactant 4 + 20 g/ha, 2, 4-D Na + carfentrazone400 + 20 g/ha, 2, 4-D E + carfentrazone 400 + 20 g/ha, halauxifen-methyl ester + florasulam + carfentrazone + surfactant 10.21 + 20 g/ha, weedy check and weed free replicated trice. All the herbicide was applied as post-emergence (30 DAS and 60 DAS) and wheat variety selected for the experiment was HD- 2967. Observation were recorded on weeds enclosed in a quadrated randomly placed in each plot. Destructive sampling was done to record weed biomass on a dry weight basis after drying in hot air oven at 60^0C.The crop was raised as per recommended package of practice for the region. Observations on growth parameters of crop were recorded at 60 DAS and yield attributes were at crop harvest. Among the herbicides treatments, application of halauxifen-methyl ester + florasulam + carfentrazone + surfactant 10.21 + 20 g/ha as post-emergence was most effective in minimizing weed infestation, with maximum weed control efficiency, and had minimumN, P and K depletion at 80 DAS and at harveststage of crop. All growth parameters (plant height (cm), number of leaves, number of tillers, crop dry weight (g/m²), yield attributes ear head/m², ear length (cm), test weight (g), grain yield (kg/ha), biological yield (kg/ha) and harvest index (%) were maximum under the application of halauxifen –methyl ester + florasulam + carfentrazone + surfactant at 10.21 + 20 g/ha.

Evaluation of Novlect TM 120 EC (a premix combination of Rinskor TM active and Cyhalofop) for broad-spectrum weed control in puddled direct-seeded rice in India

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Novlect 120 EC, a Rinskor™ active herbicide, as a pre-mix combination with cyhalofop, was evaluated in field trials conducted during 2016 and 2017 in Chhattisgarh and Andhra Pradesh provinces in India. The objective of these studies was to evaluate the bio-efficacy and dose response of Novlect for grass, sedge and broad-leaved weed control in puddled direct-seeded rice (wet DSR). Field study treatments included three dose rates of Novlect 120 EC (120,150 and 180 g/ha); bispyribac-sodium 100 SC at 25 g/ha as a standard treatment, and an untreated control. Post-emergence foliar application targeting 3 to 5 leaf stage grass weeds was done using a backpack knapsack sprayer fitted with flood jet nozzle. Treatments were arranged in a randomised complete block design with four replications. Treatments were assessed based on percent visual weed control at 15 and 30 days after application (DAA) and weed count at 30 DAA. Crop response was also evaluated at 7, 15 and 30 DAA based on a visual assessment scale of 0-7. Novlect 120 EC at 150 g/ha provided effective control (>90% visual weed control) of *Echinochloa colona*, *Echinochloa crus-galli*, *Leptochloa chinensis*, *Paspalum* sp, *Cyperus difformis*, *Ludwigia* sp. and *Bergia* sp at 30 DAA. Efficacy of Novlect 120 EC at 150 g/ha was either similar to or better than bispyribac-sodium against evaluated weeds. All the tested dose rates of Novlect were found to be safe for the rice crop. The new Novlect 120 EC herbicide demonstrated excellent control of key grasses, sedges and broad-leaved weeds with adequate crop safety providing rice growers in India a novel solution for weed management.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Evaluation of suitable encapsulation and loading materials for engineering slow release herbicide formulations for season-long weed management

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Experiment was conducted at the Centre of Innovation and Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai during 2016 to identify and evaluate a suitable encapsulation and loading materials for engineering slow release herbicide formulation for season-long weed management.

Pre-emergence herbicide oxadiargyl at the rate of 100 and 150 g/ha was encapsulated with starch and water soluble polymer (poly allyl amine hydrochloride (PAH) + poly styrene sulfonate (PSS), and loaded in biochar and zeolite at the rate of 1:1 ratio. The encapsulated herbicide along with commercial formulation was evaluated in a pot culture experiment for its releasing duration and recovery percentage. The modified herbicide formulations were characterized using Scanning Electron Microscope (SEM), Particle size Analyser and Gas Chromatography and Mass Spectroscopy (GC-MS) for its size and shape. The average particle size distribution of oxadiargyl encapsulated herbicide formulations were ranged from 0.98 µm to 2.84 µm. Particle size is very much important with respect to release of encapsulated active ingredient in a designated period of time.

The recovery percent of 89, 84, 82, 79 and 90, 87, 86, 82% was recorded with 100 and 150 g/ha oxadiargyl loaded in zeolite, biochar and encapsulated with water soluble polymer and starch, respectively. Higher herbicide releasing duration of 70 and 60 days after herbicide application was observed with oxadiargyl loaded in zeolite followed by biochar, respectively. On the other hand the oxadiargyl encapsulated with water soluble polymer and starch the duration of releasing was observed up to 50 days after application. Among the treatments commercial formulation of oxadiargyl recorded the least releasing duration of 30 and 40 days after herbicide application with 100 and 150 g/ha, respectively. The maximum half-life period of 35.3, 27.2, 21.8, 19.1 and 31.6, 28.3, 21.5, 20.2 days was recorded in the order of zeolite, biochar, water soluble polymer and starch materials loaded with 100 and 150 g/ha of oxadiargyl, respectively. Application of slow formulation of oxadiargyl at the rate of 100 and 150 g/ha did not show any significant difference in micro organism's population of bacteria, fungi and actinomycetes in pot culture. There was some reduction of microbial population during the initial stages and gradually increased with the advancement of time. The results shows that the oxadiargyl loaded with zeolite found to have higher recovery percent as well as releasing duration compared to other encapsulated or loaded formulations. Hence, the natural zeolite mineral found to be more suitable for engineering slow release herbicide formulations to achieve season-long weed control.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Bioefficacy of various herbicides in green gram and their residual effect on succeeding mustard crop

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Weed emergence in greengram begins almost with the crop emergence leading to crop-weed completion from initial stages. Although pre-emergence use of pendimethalin at 1.0 kg/ha has been found effective to control weeds in greengram but a residual herbicide is needed to control second flush of weeds emerging after rains. Further, many times weeds emerge at a later stage, which need to be controlled with post-emergence herbicides. Post-emergence herbicides imazethapyr and odessey although somewhat effective but show residual toxicity on succeeding mustard crop. Keeping in view, new herbicide Iris (Aciflourfen 16.5% + clodinafop 8% EC) RM and pyroxasulfone were tested and compared with pendimethalin alone.

The present studies were conducted during *Kharif* 2017 at Department of Agronomy, CCS HAU, Hisar. Fifteen treatments were tried in randomized block design replicated thrice. The treatments were pendimethalin + imazethapyr (TM) at 1000 g/ha as pre-emergence, aciflourfen 16.5% + clodinafop 8% EC RM at 245, 305 and 370 g/ha as post-emergence, pyroxasulfone alone at 127.5 and 150 g/ha and its combination with pendimethalin, imazethapyr and imazethapyr + imazamox (RM) at 70 g/ha and compared with pendimethalin alone and its ready mixture with imazethapyr, weed free and weedy check. Post-emergence herbicides were applied at 20 DAS (2-3 leaf stages of weeds) by knapsack sprayer fitted with flat fan nozzle using 500 L/ha water where pre-emergence herbicides amount of water used by 750 liters/ha. Observation on weeds were recorded at 20, 40 DAS and at harvest.

Post-emergence application of aciflourfen 16.5% + clodinafop 8% EC RM at all the doses was very effective against *T. portulacastrum* but its efficacy against *C. rotundus* was poor. Pyroxasulfone alone at 127.5 and 150 g/ha and its combination with pendimethalin proved effective against all weeds. PRE use of pyroxasulfone alone at 127.5 g/ha and its combination with pendimethalin proved good control of *C. rotundus* whereas pendimethalin was not at all effective against this weed. Pre-emergence treatment of pendimethalin in combination with imazethapyr at 1000 g/ha were very effective to minimize *Trianthema* population. At 30 DAS, WCE was maximum (93.6%) with aciflourfen 16.5% + clodinafop 8% EC RM at 370 g/ha followed by its lower (91.5%), 93% with pyroxasulfone at 127.5 g/ha and 90.2% with pre-emergence use of pendimethalin combination of imazethapyr (RM) at 1000g/ha. At 50 DAS, maximum WCE (91.2%) was recorded with post-emergence use of aciflourfen 16.5% + clodinafop 8% EC RM at all rates followed by pyroxasulfone (85%) and imazethapyr + pendimethalin (RM) at 1000 g/ha (83%).

Maximum number of pods/plant and number of seeds/pod were highest in weed free and two hand weeding treatments which were statistically at par with all aciflourfen 16.5% + clodinafop 8% EC treatments. Seed yield was maximum (1290 kg/ha) with use of aciflourfen 16.5% + clodinafop 8% EC RM at 370 g/ha which was significantly at par with its lower dose 305 g/ha and weed free significantly higher than all other treatments. None of the treatment except imazethapyr aloneandin combination with imazamox (RM) or quizalofop applied in green gramcaused 43-73% toxicity to succeeding mustard crop with heavy yield penaltyand reduction in plant height, no. of leaves/plant dry matter accumulation/plant of mustard as compared to untreated check and other herbicide treatment.

Effect of pre-and post-emergence herbicides on weed growth and yield of maize and their residual effect on succeeding greengram

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Maize (*Zea mays* L) is one of the most efficient crop which gives high biological yield as well as grain yield in a short period of time due to its unique C_4 photosynthetic mechanism. Maize being a rainy season crop and sown at wider spacing coupled with slow initial growth results in heavy weed infestation. The extent of yield loss due to weeds in maize varies from 28 to 93 per cent depending upon the type of weed flora, intensity and duration of crop weed competition. Purple nutsedge **(***Cyperus rotundus* L**)** is one of the most troublesome perennial weed during *Kharif* and ranked as one of the world's worst weeds in 52 crops and in more than 90 tropical and sub-tropical countries. Keeping all these in view, a field experiment was carried out on sandy loam soils of wetland farm of S.V. Agricultural College, Tirupati, Andhra Pradesh, India during *Kharif* 2016with ten weed management practices to study the effect of pre (alachlor 1000g/ha) and post-emergence (tembotrione 100 g/ha and/halosulfuron-methyl 67.5 g/ha) herbicides on weed growth and yield of maize and their residual effect on succeeding greengram. The test variety for maize and greengram was '*DHM-117*' and '*WGG-42*', respectively. The predominant weeds associated with *Kharif* maize were *Cyperus rotundus* (55%), *Digitaria sanguinalis* (12%), *Boerhavia erecta* (8%), *Borreria hispida* (6%), *Trichodesma indicum* (5%), *Phyllanthus niruri* (4%) and *Digera arvensis* (3%). Pre-emergence application of alachlor 1000 g/ha *fb* tank mix application of halosulfuron-methyl 67.5 g/ha + tembotrione 100 g/ha recorded significantly lesser density and dry weight of weeds with higher WCE which was being at par with two hand weedings at 20 and 40 DAS. Post-emergence application of tembotrione 100 g/ha effectively controlled the grassy weeds whereas halosulfuron-methyl 67.5 g/ha was effective in controlling *Cyperus rotundus*. Tank mix application of halosulfuron-methyl + temotrione might have synergistic effect in controlling the *Cyperus rotundus* than application of both the herbicides individually. Significantly higher number of grains/cob, hundred grain weight, grain yield and straw yields of maize were recorded with pre-emergence application of alachlor 1000 g/ha *fb* tank mix application of halosulfuron-methyl 67.5 g/ha + tembotrione 100 g/ha, however higher benefit-cost ratio was obtained with pre-emergence application of atrazine 1000 g/ha *fb* post-emergence application of 2,4-D sodium salt 800 g/ha. Different pre-and post-emergence herbicides applied to *Kharif* maize did not exerted significant influence on germination per cent of succeeding greengram. However, higher seedling vigour index of succeeding greengram was recorded in the plots treated with pre-emergence application of alachlor 1000 g/ ha *fb* post-emergence application of halosulfuron-methyl 67.5 g/ha + tembotrione 100 g/ha. The present study has revealed that pre-emergence application of alachlor 1000 g/ha *fb* halosulfuron-methyl 65.7 g/ha + tembotrione 100 g/ha (tank mix) applied at 20 DAS was found best weed management practice to enhance the productivity and returns, besides effective control of mixed weed flora in *Kharif* maize. Pre-emergence application of alachlor 1000 g/ha + post-emergence application of halosulfuron-methyl 65.7 g/ha found to be effective to control purplenut sedge (*Cyperus rotundus* L.)

Poster presentations

Theme 1

Weed biology, ecology and climate change

Impact of climate change on crop-weed dynamics

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Climate change influences not only the performance of individual plant species but may also impact interactions with other species at different growth stages. Increase in atmospheric CO_2 and temperature are two most important drivers involved in climate change. Weeds are known to possess better adaptability to the changing environment than crops by virtue of greater genetic diversity and evolutionary potential. Evidences indicate that weeds may show a strong response to changes in climate. The present study was conducted in open top chambers in system based approach using rice-wheat-summer greengram cropping sequence. Crops (rice, wheat and greengram) alongwith their dominated weeds were subjected to long-term exposure to ambient conditions, elevated CO_2 (550 ± 50 ppm), elevated temperature (ambient + 2 °C) and combination of these two factors (elevated CO_2 and elevated temperature). Observations on morpho-physiological, phenological, biochemical parameters, activity of soil enzymes and analysis of gene involved in antioxidant defence pathway were recorded periodically. Elevated CO_2 affects overall growth of crops as well as weeds, however, elevated temperature alone or in combination of elevated CO_2 had adverse effect on phenology, growth and development of the crops (more so in rice and wheat). Photosynthesis, antioxidant defence mechanism and expression analysis of gene involved in photosynthesis and antioxidant defence have been studied in detail in crops and weed species. Regulation of new iso-forms of antioxidant enzymes in response to elevated CO_2 and elevated temperature and combination of these two was evident in species-specific manner. Weeds exhibited stronger antioxidant defence as compared to crop counter parts. Expression of genes involved in photosynthesis and defence pathways was found to be altered in species-specific and treatment-specific manner. Expression of genes involved in antioxidants defence pathway altered which points towards involvement of these genes in adaptation to high temperature and high CO_2 environment. Elevated CO_2 and temperature influenced the activity of soil enzymes (FDA hydrolysis, dehydrogenase and urease) in rhizosphere of crops and weeds and again such effect was found to be specific to the species. *E. crus-galli* responded positively with respect to the soil enzymes at elevated CO_2 alone or in combination of temperature. Efficacy of sulfosulfuron against *P. minor*, and bispyribac-Na against *E. colona* reduced at elevated CO_2 and elevated temperature suggesting that weed management would be more difficult in coming future due to climate change. Elevated CO_2 and elevated temperature individually and in combination affected phenology and yield of crops, however magnitude varied depending on the species. From the results, it can be inferred that at elevated CO_2 and temperature, physiology and phenology of crops especially rice and wheat affected adversely, while associated weed species performed better than crops. Further, crop-weeds interaction may change in favour of weeds, however such effect would be specific to species.

Occurrence of host-specific races of *Orobanche aegyptiaca* in Banda district of Uttar Pradesh: A new report from India

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Herein, the physiological races of root holoparasite, *Orobanche aegyptiaca* in Banda district of India were determined. Since several years *O. aegyptiaca* has been found to be infecting many economically important crops in this area. One hundred spikes of *O. aegyptiaca* infecting brinjal plant (*Solanum melongena*) were collected from 20 different *viz.*, Atarra, Barokhar, Bisanda, Chilla, Gazipur, Hardauli, Jalalpur, Jakhni, Jamwara, Jaspura, Kalinjar, Kurrahi, Lakhanpur, Mahua, Naraini, Oran, Palhari, Pangara, Reona and Tarkhari of Banda districts of Uttar Pradesh. The seeds collected from each spike were used to infect a set of nine different plants namely brinjal (*Solanum melongena* var. Sukdha), carrot (*Daucus carota*var. Redking) chickpea (*Cicer arietinum* var. Avrodhi), chili (*Capsicum annuum* var. US 917), fenugreek (*Trigonella foenum-graecum* var. UM-12), linseed (*Linum usitatissimum* var.Padmini**)**, mustard (*Brassica juncea* var. Pusa mustard 24) sunflower (*Helianthus annuus* var. Advanta) and tomato (*Solanum lycopersicum* var. K-21). The *O. aegyptiaca* populations showed the of host preference and levels of attachment per plant also varied amongst the differential host plants.The results revealed the occurrence of two type of physiological races of *O. aegyptiaca* namely Race-A and Race-B, on the basis of infection on the different host plant used in this study. The Race-A of *O. aegyptiaca* infected all the nine test host plant, whereas Race-B of *O. aegyptiaca* infected only six hosts *viz.* brinjal, chili, fenugreek, mustard, tobacco and tomato and remaining three plants namely carrot, linseed and sunflower showed non- host response. These findings showed that the Race-A is more virulent on brinjal, tomato, and mustard crops as compared Race-B. Whereas, Race-B is more virulent on chickpea. Moreover, both Race-A and B are equally virulent on fenugreek. The Race-A was prevalent in all the twenty localities, while Race- B was restricted to only five localities *viz.*, Jamwara, Kalinjar, Naraini, Palhari and Tarkhari. The frequency of occurrence of Race-A was higher as compared to Race-B in brinjal fields. The most important findings of our study showed the infection of *O. aegyptiaca* Race-A on fenugreek and linseed. To the best of our knowledge, so far no information is available regarding the parasitism on fenugreek and linseed. Hence this document revealed as the first report of *O. aegyptiaca* infection on fenugreek and linseed from India as well as abroad. In addition to this, the brinjal plants infected by two races namely A and B of *O. aegyptiaca* in Banda district also constitute the first report from India. These results may be useful in the management practices like in crop rotation and development of the species or race specific resistant varieties of brinjal. In future, further investigations shall be conducted on host preference of other populations using these set of crops in addition to other crops, which may provide better insight to the occurrence of races of *O. aegyptiaca*.

Digitisation of weed species herbarium at ICAR-IGFRI, Jhansi

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Weeds generally compete with crop for natural and applied resources, cause yield losses in the range of 10-80% and thereby affect the quality and quantity of agricultural productivity. Manual weeding is practised traditionally but the increased labour scarcity and costs are forcing farmers to adopt labour and cost saving options. Identification of weeds is an important issue in weed science as identifying troublesome weed species is the foundation of sound weed management. Accurate identification of weeds is critical at the time of emergence of seedling for selecting an appropriate post-emergence herbicide. Herbarium preparation is also an important part of taxonomy which provides material for easy identification. Physical specimens are sometimes damaged during handling and due to dust, dirt, insect, mould, humidity, temperature, light etc. Therefore, digitized images, on the other hand can help save the quality of images besides saving valuable time in searching any particular taxon. Major herbarium collections were made during 1960s-70s under the Grassland Survey Scheme of PL-480 project of ICAR from all over India. The collected specimens were identified with the help of relevant taxonomic literature and the identity was confirmed by matching them with the authentic specimens of Central National Herbarium and ICAR-NBPGR, New Delhi. The plant specimens were identified with the assistance of available floras and nomenclature was also updated with the help of available literature. The plants were arranged alphabetically along with their family. Brief taxonomic account on each herbarium along with information on habitat, occurrence, place and date of collection, name of collector were documented and housed at ICAR-IGFRI. Taxonomic literature and study of herbaria revealed, a total of 113 numbers of species under 97 genera belonging to 31 families. Out of 31 families, 19 families are represented by single species. Poaceae is the first dominant family where as Fabaceae and Asteraceae are the 2nd and 3rd largest family, respectively. Among the 113 species, 70 species of dicots are distributed under 62 genera belonging to 27 families, while 43 monocot species spread over 35 genera under 4 families. It is interesting to note that out of 43 species of monocots 38 species are sedges and grasses, which constitute 88.37% of the total monocots. The approximate ratio of monocot and dicot species is 1:1.2. So it indicates that dicots are represented more than the monocots.

Salt stress tolerant and as a food crop for sustainable nutritional security: *Physalis* species

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Agriculture is under pressure to produce greater quantities of food, feed and biofuel on limited land resources. Current over-reliance on a handful of major staple crops has inherent agronomic, ecological, nutritional and economic risks and is probably unsustainable in the long run. Wider use of today's underutilized minor crops provides more options to build temporal and spatial heterogeneity into uniform cropping systems and will enhance resilience to both biotic and abiotic stress. The study of salt stress mechanisms in plants has become an important issue for the modern agricultural development, climate change and global food crisis. The plant response to high salt concentrations is complex and comprehensive; it includes many different processes, which should be correctly coordinated. Salt stress is one of the most devastating abiotic stresses which severely affect the agricultural productivity in various ways. High concentration of salt in the soil or in the irrigation water can have an overwhelming effect on plant metabolism, disrupting cellular homeostasis and uncoupling major physiological and biochemical processes. Salinity cause both osmotic stress and ionic toxicity which hamper the plant productivity by inhibiting or altering the plant growth, dry matter partitioning, seed germination, photosynthesis and yield. Domestication of weedy relatives of crop species may provide additional income from farming, as well as resilience to climate variability and scarcity of resources, such as salt. Different ecotypes of *Physalis peruviana* and *Physalis minima* were collected from different locations of India. Seedlings were grown in nursery and transplanted in field after 15 days. Salt stress experiment was carried out in pots. Observations on growth, physio-biochemical and molecular aspects, yield and nutritional status were recorded of two *Physalis* species (*P. minima* L. and *P. peruviana* L.). *Physalis* plants were grown under control, 200 mM and 400 Mm salt (NaCl) concentration. Results revealed both the species tolerate high degree of salt stress without showing any injury symptoms.The growth of both the species decreased with increasing level of NaCl stress, significantly higher rates of photosynthesis and transpiration, stomatal conductance were noticed in *P. peruviana* as compared to that in *P. minima* under control treatment as well as under salt stress treatments. Higher RSI was recorded in *P. minima* as compared to that in *P. peruviana* under control treatment as well as under salt stress treatments. Isoenzyme patterns of superoxide dismutase and stronger activity of antioxidant enzymes suggest species-specific differential regulation and induction of new isoforms under control treatment as well as under salt stress treatments. From the study, it may be concluded that *P. peruviana* was found to possess significant tolerance against salt stress in comparison to *Physalis minima*. This is the first report on this aspect. Fruits of four morphologically different ecotypes of *Physalis* were analyzed for mineral contents (Fe, Mn, Zn, Ca, K, Mg, Na, P and S) and â-carotene. Acceptability of fruits at consumer end and richness in mineral content, such as Fe and Ca and â-carotene in *Physalis* fruits is of immense significance in fighting malnutrition in developing countries. Results of the study suggest that *P. minima* and *P. Peruviana* are climate resilient, of high nutritional value, and potentially acceptable at consumers' end and profitable to the farmers to grow. Keeping in view these characteristics, *Physalis* species are worthy of further consideration as a food crop for sustainable nutrition security.

Performance of winter maize and dominated weeds under climate change scenario

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Global warming has become a major issue in the last decade and got acceptance throughout the world. Two environmental factors, elevated CO_2 and temperature, directly related to the physiology of crops and productivity. Increase in atmospheric CO_2 concentration directly affects photosynthetic efficiency and the associated metabolic processes. Similarly, increase in temperature also have significant effects on all the physiological and metabolic processes mediated by enzymes. Changes in these factors are likely to have significant direct and indirect effects on biology of crops and weeds and competition among them. Weeds are known to possess better adaptability to the changing environment by virtue of greater genetic diversity and evolutionary potential than crops. There are plants with three different types of photosynthetic pathways *i.e.* C3, C4 and CAM. Each one presents unique characteristics in regard to absorption and assimilation of the CO_2 as well as to the adaptation to temperature variations. These different types of plants show changes in physiology, morphology, anatomy, chemistry and gene expression profile when grown in elevated CO_2 concentrations and high temperatures. Evidences indicate that weeds may show a strong response to changes in climate. Hence, efforts have been made to study effect of elevated CO_2 and temperature individually and in combination on crop and dominant weeds at physiological, biochemical and molecular level. The present study was conducted in winter maize with associated dominated weeds (*Chenopodium album* and *Phalaris minor*) in OTCs in at ICAR-DWR, Jabalpur. Plants of each species were subjected to long-term exposure to elevated CO_2 (550 ± 50 ppm), elevated temperature (ambient ± 2 °C) and combination of these two (elevated CO_2 and elevated temperature). For comparison, control treatment was maintained at ambient CO_2 (390 ± 5 ppm) and ambient temperature. Morpho-physiological, phenological, biochemical and activity of antioxidant enzymes observations were recorded in each species. Elevated CO_2 had a positive effect on overall growth of crops as well as weeds, however, elevated temperature alone or in combination of elevated CO_2 had adverse effect on phenology, growth and development of the crops (more so in maize). Photosynthesis, antioxidant defence mechanism and expression analysis of gene involved in photosynthesis and antioxidant defence have been studied in detail in crops and weed species. Weeds exhibited stronger antioxidant defence as compared to crop counterparts. Expression of genes involved in photosynthesis and defense pathways was found to be altered in species-specific and treatment-specific manner. Expression of genes involved in antioxidants defense pathway altered which points towards involvement of these genes in adaptation to high temperature and high CO_2 environment. Elevated CO_2 and elevated temperature individually and in combination affect phenology of crops as well as weeds depending on the species. Elevated CO_2 and temperature influenced the activity of antioxidant enzymes (POX, catalase, carbonic anhydrate, GR and SOD) in crops and weeds. *Chenopodium album* responded positively with respect to the antioxidant enzymes at elevated CO_2 alone or in combination of temperature. At elevated CO_2 and temperature, crop-weeds interaction altered in species-specific manner. Physiology and phenology of crops especially maize affected adversely, while associated weed species perform better than crops.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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DNA barcoding for identification of *Cyperus* species of India

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Cyperus is the second largest genus of the sedges or Cyperaceae/Cyperae family, the plants of which are identified as one of the most common agricultural weeds. It is a large genus of more than 700 species of sedges, dispersed all over continents in both tropical and temperate regions as annual or perennial plants. Generally, they are considered as obnoxious weed in the agriculture field because they directly affect the crop production and yield. Although some of the sedge plants have medicinal importance and are used for treating many diseases. They possess various pharmacological activities such as diuretic, anti-inflammatory, anti-dysenteric, antirheumatic, anthelminthic, analgesic and carminative activities. Considering above mentioned facts, the identification of *Cyperus* species of medicinal importance is essential. One of the best taxonomic methods is DNA barcoding, a short genetic marker in an organism's DNA can be used to identify it as belonging to a particular species. DNA barcoding has been proved to be a system for quick and accurate species identification which will make ecological system more accessible. It differs from molecular phylogeny in that the main goal is not to determine patterns of relationship but to identify an unknown sample in terms of a pre existing classification. Although barcodes are sometimes used in an effort to identify unknown species or assess whether species should be combined or separated, the utility of DNA barcoding for these purposes is subject to debate. A desirable locus for DNA barcoding should be standardized (so that large databases of sequences for that locus can be developed), present in most of the taxa of interest and sequenceable without species-specific PCR primers, short enough to be easily sequenced with current technology, and provide a large variation between species yet a relatively small amount of variation within a species.

In present study, a total of 82 sedge plants were collected from areas covering seven states of India. The plant species and morphological variations among different species were determined based on overall plant growth characteristics. The samples were identified as belonging to 17 different species of *Cyperus* and related genera on the basis of UPGMA cluster analysis using Jaccard and Simple Matching coefficients. DNA barcoding of the collected sedge plant samples was done using two plastid based barcode loci *rbcL* and *matK*. Barcode loci *rbcL* generated 36 barcodes of length 314-347 bp and *matK* in 17 samples of length 540-826 bp. All the barcode sequences were deposited in GenBank and assigned accession numbers. Similarity based searches through BLASTn and BOLD plant identification tools revealed eight unique species specific barcodes generated in present study which has not been reported in the GenBank for the same locus and species. In present study, based on UPGMA and Maximum parsimony analysis *rbcL* + *matK* was found the best barcode loci followed by *matK* resolving monophyletic cluster for the individual species. The *rbcL* + *matK* was also found the best barcode loci for DNA barcoding in *Cyperus* spp.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Emergence of two invasive weeds in Punjab: *Verbesina encelioides* and *Hyptis suaveolens*

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Invasive species are element of global change, pose a major threat to the biodiversity and cause homogenization of world's flora. These are found in different parts of India and Punjab is no exception in this regard. Many invasive weeds have paved their way in the state and have a serious impact on the native flora and ecosystems. Two such weeds are *Verbesina encelioides* (Cav.) Benth.and Hook. f. ex A. Gray. and *Hyptis suaveolens* (L.) Poit., which have now established themselves in the available empty niches and are proving to be harmful to the local vegetation.

Verbesina encelioides, an Asteraceae member, commonly known as wild sunflower or golden crownbeard, is an annual arable weed from tropical America attaining a height of about 1.5 m with small, yellow sunflower like capitula. The plant is fast intruding various habitats and forming its own colonies. It has been reported to be invading in the tropical and sub-tropical regions of the world. Its invasive attributes include high seed production, seed dormancy, and ability to tolerate dry and high temperature conditions. It can be seen growing luxuriantly along the road sides, railway tracts, open areas, agricultural boundaries and forest margins. It possesses high degree of adaptability to various environmental conditions which helps in its establishment in new environments.

Another weed *Hyptis suaveolens* (commonly called pignut, bush mint) is a highly aromatic annual weed belonging to family Lamiaceae. *H. suaveolens* is a pantropical aggressive weed native to Tropical America. It is an erect herb with broad leaves attaining a height of almost 2 to 3 metres during its growing season. Due to its ruderal nature, it has now become a noxious weed spreading to other warmer tropical countries of the world. Nowadays, it has become naturalized in many countries including India due to deliberate or accidental introductions. It can be commonly found growing along roadsides, disturbed areas, open forest lands and other wastelands.

These weeds are considered as noxious as they replace the native floral diversity along the roadsides and other open areas. These plants form dense monocultures over disturbed and degraded areas. They release certain allelochemicals that strongly inhibit the growth of other plant species growing in their vicinity. In this manner, *V. encelioides* and *H. suaveolens* gain a competitive advantage above other native plant communities and out compete them. Keeping in mind the rapid spread of these weeds, the present study focuses on the various biological and ecological characteristics that contribute towards their invasiveness.

Comparative analysis of gene expression in response to salt stress in diverse weedy rice biotypes

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Weedy rice (*Oryza sativa f. spontanea*) has become a menace in many rice growing areas. Weedy rice can be regarded as biosimilar having attributes similar to cultivated and wild rice, and therefore is difficult to manage. Characterization of functional traits of among different weedy rice population from different agro-climatic zones revealed marked differences in morphological, growth and reproductive behaviour. The variations existing in weedy rice population are a major reason for its wider adaptability to varied environmental conditions and also create problem for its management in rice crop. Adverse effects of salinity on rice cultivars have been documented by many researchers in India or elsewhere. Locally adapted germplasm have been shown great resilience against adverse environmental conditions like salinity and water deficit. Weedy rice can be a good genetic source for developing salt-tolerant as well as weed-competitive rice cultivars. Objective of this study was to evaluate the gene expression and identify their functions in controlling ROS levels in weedy rice. A total 45 entries were examined including 41 entries of weedy rice collected from different geographical regions of Madhya Pradesh along with one wild rice (*Oryza nivara*) and three cultivars. Entries were evaluated for tolerance to NaCl stress at the seedling stage. Data were recorded for 30 days for different germination parameters. Significant variability was observed for evaluated traits among the weedy rice biotypes studied. Based on the screening results, three weedy rice accessions *WR-15*, *WR-18* and *WR-56* performed well under salt stress condition. Best performing biotypes were selected for gene expression analysis along with check cultivars. Total RNAs were isolated from selected germplasm and used further for cDNA synthesis. The RT-PCR analysis was done using 13 gene-specific primers. The analysis indicate possible involvement of these genes in tolerance mechanism against salt stress. Results showed that salt-tolerant weedy rice that could be a more suitable genetic resource for the development of rice cultivars having enhanced salt tolerance. Our research also gene involved in antioxidant defence pathways play a significant role in salt tolerance. Our research provided a background to identify genes responsible for salt stress tolerance and weedy rice can be explored for rice improvement using molecular approaches such as marker-assisted breeding methods.

Weed ecology and weed competition

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Weed Ecology is the study of reciprocal relationship between organism and their environments. The ecology of weed is concerned with growth characteristics and adaptation that enable weed to exploit the ecological niches left open in those environments altered by man for his use and the survival mechanisms where by weeds persist in such environment. It is study of only onepopulation *i.e.* how and indivisual species in a population interacts with is environment at all stage of its life cycle. The study of relationship between communities of different weed species with their environment is called weed synecology. The green vegetation that initially invaded the bare rock is slowly replaced by second type, which itselfis replaced by third type in course of time. For successful cultivation of various crops, optimum climate and adaphic condition are required, wild oats *(Avena ludoviciana*) is another trouble some grass type weed of *Rabi* season crops. On the other hand, swank (*Echinochloa crusgalli)* and kanki (*Ischaemum rugosum*) are grass weeds which are invariably associated with rice as the frequent flooding growth of this weed. The crop weed association goes on changing with the change in agronomic practices especially cropping system and with the continous use of same group of herbicide. Morphological similar weed are difficult to control both by mechanical or chemical method *e.g.* plant of *Echinochloa crusgalli* (swank) which resemble with rice are often uprooted which rice nursery and well grown plants of this weed when transplanted with rice seedling are not controlled with any of the herbicide recommended for this crop majority of weed plant complete their life cycle before the maturity/harvest of the crops in which they are associated. The seeds of few weed seeds is of the same size as of the crop grain seed and this cannot be separated out even by through sieving. The weed seeds which have the tendency to germinate in many flushes are very difficult to control both which mechanical or chemical method. The continous use of single group of herbicide over year leads to resistance phenomenom. There are few weed which are only associated with a particular hosts in the absence of host plants this weed seeds show no germination even when the seeds are in viable conditions. The occurrence of weed in a particular locality depends upon many factors and the importances are: 1. physiographic 2. edaphic 3. climatic. These factors relates to the form and behaviour of the earth's surface and the distribution of a weed plants is highly dependent on physiographic factor which includes geology of soil, topography, altitude, exposure to sunlight as well as direction of mountains *etc.* soil is the top cover of the earth in which plants can grow.

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Weed seed bank dynamics under prominent land use systems of dryland agro-ecosystem of eastern Uttar Pradesh

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Land-use systems (LUS) are the surface utilization of land at a given space and time. Agroforestry, orchard and annual cropping system are the three prominent LUS of Eastern Uttar Pradesh. Although, a large number of constraints faced by these LUS, of which weeds cause yield loss of up to 98%. Therefore, there is an urgency to devise an integrated weed management practices, for which knowledge of the weed seed bank (WSB) is required, which is generally not given due importance in India. Keeping these facts in view, the present investigation was undertaken.

An experiment was conducted in the factorial randomized block design during *Kharif* 2017 in the adjoining areas of RGS Campus, BHU, Barkachha, Mirzapur (U.P.), and replicated thrice. Factor-1 comprised of three LUS (agroforestry, pure orchard and annual cropping system), whereas, factor-2 and factor-3 comprised of two altitudinal ranges (lowland and upland) and two soil depth (0-15 cm and 15-30 cm), respectively. From experimental plots soil samples were taken on 30th June 2017 with the help of soil auger, having 5 cm diameter. After post-treatment of samples (including removal of the large rocks and root fragments), they had been placed on the perforated aluminium trays and watered daily to maintain soil moisture content close to field capacity. Data on emerged seedling had been recorded once a week.

Pure orchard system recorded significantly lowest density of the sedges and broad-leaf weeds (BLWs), although annual system showed at par BLWs density to that of a pure orchard. Grasses density didn't differ with LUS. Lower sedges and BLWs density under pure orchard could be attributed to higher planting density of trees, which leads to dense canopy formation and reduced light penetration up to ground level. These conditions didn't favor weed infestation and weed seed formation. A higher density of BLWs under agroforestry system was attributed to better light interception *vis-à-vis* higher moisture and nutrient content favors the growth and seed formation by BLWs.

Lowland area showed the highest infestation of sedges. Actually, soils of upland area usually have lower soil moisture content these conditions normally didn't favor the growth of purple nutsedge. Simultaneously, the upland area produced a significantly higher density of BLWs because, in general, in this area, *Oldenlandia corymbosa* is the predominant BLW. This weed requires low moisture habitat for growth and produces enormous seeds. Thus, upland area, being lower moisture content, favors the growth of predominant BLW and recorded higher WSB. The density of grassy weeds didn't differ among the altitudinal range.

The density of all weeds recorded inversely relationship with the soil depth which may be due to the higher organic carbon, available nitrogen, phosphorus and lower bulk density than subsurface soil.

Above-said study on WSB dynamics reveals that pure orchard system showed the lowest infestation of weeds followed by the annual crop system and highest infestation in agroforestry system. Upland areas have a lower infestation of sedges; contrarily it showed the highest density of broad-leaved weeds. The top layer of the soil profile recorded the highest density of all weeds as compared to sub-surface soil.

Weed floristic diversity of the agro-ecosystems of Himachal Pradesh

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Invasion by troublesome weed species is one of the major contributors in loss of potential crop yield. Therefore, weed flora associated with different crops in Himachal Pradesh was investigated. The phyto-sociological survey work was undertaken from 1980s to 2016-17. During *Kharif*, nine districts like Chamba, Hamirpur, Kangra, Kinnaur, Kullu, Mandi, Sormour, Solan and Una were surveyed in 545 quadrats. While in the *Rabi*, four districts, *viz.* Chamba, Kangra, Sirmour and Solan were covered in 350 quadrats. Based on extensive field surveys, it was revealed that 176 plant species were growing as weeds in different agro-ecological situations of Himachal Pradesh which belonged to 111 genera and 43 plant families. In *Kharif*, out of 137 species, 68 species in Chamba, 23 in Hamirpur, 51 in Kangra, 53 in Kinnaur, 66 in Kullu, 64 in Mandi, 41 in sirmour, 51 in Solan and 37 weeed species in Una were recorded. *Digitaria sanguinalis* was most important weed with IVI of 18.8 followed by *Ageratum conyzoides* (16.7), *Commelina benghalensis* (15.1), *Echinochloa colona* (13.7), *Cyperus iria* (13.4), *Galinsoga parviflora* (9.8), *Polygonum alatum* (7.8), *Eleusine indica* (7.8), *Cyperus difformis* (6.9), *Cenchrus biflorus* (6), *Dactyloctenium aegypticum*(5.8) and *Setaria glauca* (5.2) in *Kharif*. While in *Rabi*, out of total 89 species, 45 species in Chamba, 69 in Kangra, 56 in Sirmour and 35 in Solan were noticed. *Medicago denticulata* (20.3) was the most important weed and was followed by *Anagallis arvensis* (19). Out of all 176 species infesting agro-ecosystems of Himachal Pradesh, 50 were found growing during both the seasons while 87 species were exclusively growing in *Kharif* and 39 in the *Rabi* season only. Poaceae was the most dominant family with 23 genera and 35 species followed by Asteraceae (17 genera and 22 species), Cyperaceae (5, 14), Fabaceae (7, 14), Polygonaceae (3, 12), Amaranthaceae (5, 7), Brassicaceae (5, 6) and Convolvulaceae (2, 5). Commelinaceae and Lamaceae had 4 species each; Caryophyllaceae, Malvaceae, Oxalidaceae and Plantaginaceae 3 species each; Boraginaceae, Chenopodiaceae, Equisitaceae, Geraniaceae, Liliaceae, Rosaceae and Solanaceae had two species each. Rest of the 21 families had one species each. Irrespective of the season, *Digitaria sanguinalis* topped as the most important species with IVI of 12.6 followed by *Ageratum conyzoides* (12.0) and *Commelina benghalensis* (10.0), *Echinochloa colona* (9.1), *Cyperus iria* (9.0), *Galinsoga parviflora* (8.3).

Studies on morphology, growth behaviour and seed production capacity of different species of weedy rice

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Weedy rice has been identified as one of the most troublesome weeds seriously affecting rice production especially in direct seeded rice. It is a superior competitor to cultivated rice owing to its early vigour, greater tillering and height of plants. The extent of yield loss due to weedy rice in West Bengal with 10-15% infestation has been reported to be in the range of 12-17%. Its morphological similarity with rice renders the hand weeding ineffective. Again, its biochemical and genetic similarities with cultivated rice make herbicidal control impossible. Before planning for efficient weed management programme it is essential to study the morphology, growth behabiour and seed production capacity of such troublesome weed. The present experiment was conducted in 2013 to study the morphology, growth and seed production capacity of different weedy rice species. The experiment was laid out in a randomized block design with five replications in earthen pots. The four different weedy rice genotypes *viz. O. rufipogon, O. nivara, O. barthii* and *O. minuta* were taken as treatments. Data were subjected to analysis of variance (ANOVA) using MS-Excel worksheet. Plant height at maturity, culm length, Leaf length and width, ligule length, panicle length, spikelet, colour of spikelet, colour of nodes and internodes, awn length, awn colour, apiculas colour, stigma colour, 1000 grain weight (g), grain length and width (mm) were recorded for the morphological study of the different species of weedy rice. The highest plant height was observed in *Oryza rufipogon* (138.1 cm) which was statistically at par with *O. barthii* (129.9 cm) and *O. nivara* (128.4 cm). The lowest plant height was observed in *O. minuta* (104.7 cm). The lowest number of tillers/plant at maturity was recorded by *Oryza rufipogon*. The highest number of tillers at maturity was registered by *O. nivara* (28.2) which was statistically at par with *O. minuta* (26.8) and *O. barthii* (23.6). The highest number of panicles/plant at maturity of weedy rice was recorded by the species *O. nivara* (26.8) which was statistically at par with the species *O. minuta* (22.4). The species *O. minuta* registered the highest number of seeds/plant (1901.2) which was statistically at par with *O. nivara* and *O. barthii*. The lowest number of seeds/plant was recorded by the species *O. rufipogon* (810.8). Among the weedy rice species, *O. rufipogon* registered the lowest 1000 seed weight (11.9 g). On the other hand the highest 1000 seed weight was recorded by the species *O. minuta* (23.5 g) followed by *O. barthii* (21.3 g) and *O. nivara* (20.2 g).

An updated information on negative and positive traits of *Parthenium hysterophorus* (carrot grass) in India and abroad

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Parthenium hysterophorus is a noxious weed in Indian sub-continent. This weed is considered to be a cause of allergic respiratory problems, contact dermatitis, mutagenicity and many other ailments in human and livestock. Crop production is drastically reduced owing to its allelopathical effect of *Parthenium hysterophorus*. Also aggressive dominance of this weed threatens biodiversity. Eradication of *P. hysterophorus* by burning, chemical herbicides, eucalyptus oil and biological control by leaf-feeding beetle, stem-galling moth, stem-boring weevil and fungi have been carried out with variable degrees of success.

Recently many innovative uses of this hitherto notorious plant have been discovered. *Parthenium hysterophorus* confers many health benefits, *viz* remedy for skin inflammation, rheumatic pain, diarrhoea, urinary tract infections, dysentery, malaria and neuralgia. Its prospect as nano-medicine is being carried out with some preliminary success so far. Removal of heavy metals and dye from the environment, eradication of aquatic weeds, use as substrate for commercial enzyme production, additives in cattle manure for biogas production, as bio-pesticide, as green manure and compost are to name a few of some other potentials.

Parthenium hysterophorus is a notorious weed and became menace in India and other countries. Efforts are therefore, being made to manage the weed by different methods. Emphasis has been given during the last few years to control the *Parthenium* weed through biological agents like insects, pathogens and competitive plants. Among insects, *Zygogramma bicolorata* was found most effective, having wider adaptability and it can bring weed population to insignificant level.

Keeping this in perspective, present attempt was made to update and explore the update information on Negative and positive traits of *Parthenium hysterophorus* and important works done on bio-control of *P. hysterophorus*, poses as a weed, the effective control measures that can be implemented as well as to unravel the latent beneficial prospects of this weed.

Parthenium weed growth behavior under elevated CO_2 concentration and temperature a review

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Climate change is happening at a rapid pace around the globe which is significantly impacting the plant growth and ecosystem dynamics. Weeds are major threat to agriculture and biodiversity as they out-compete crops and native species and contribute to land degradation. Changes in geographic distributions, abundances and life-cycles of weeds are the likely outcome of the effect of climate change. Natural evolution and certain specific characteristics such as short life cycles, dispersal mechanisms, may give the weeds a competitive advantage over less aggressive species under changing climate. Early growth of parthenium weed was greater under an elevated atmospheric CO_2 concentration than under an ambient CO_2 level warm conditions (both those of the present and those predicted under climate change) are likely to advance the development of parthenium weed, creating a shorter life span but a greater plant height and biomass. Warm conditions will also promote the reproductive ability of parthenium weed, by promoting seed production and seed fill percentages, promoting dormant seed production and producing seed with the capacity to live longer in the soil seed bank. Dry conditions promoted the speed of development, thereby shortening the life span and creating a greater plant height and biomass. The increase in photosynthetic rate due to elevated CO_2 was compromised by an increase in transpiration rates at very high temperature (47 ^{0}C). Parthenium weed biomass was significantly increased at a high CO_2 concentration (550 ppm).

Strong morphological features and a unique reproductive biology enables parthenium weed to adapt to a wide range of environmental conditions. An efficient photosynthesis mechanism, tolerance to numerous abiotic stresses, and unique soil interactions are parts of the physiological component of parthenium weed invasion. Parthenium weed plant produces a variety of allelochemicals, and releases them in multiple ways, that helps the weed to suppress neighboring plants. So, allelopathy may be another component of the parthenium weed invasion mechanism. In addition to these morphological and physiological aspects, greater genetic diversity and improvement in growth and reproductive capacity under a changing climate are also thought to be the important phenomena contributing towards its invasion success. Growth at elevated CO_2 would result in anatomical, morphological and physiological changes that could influence herbicidal uptake rates, besides translocation and overall effectiveness. The physiological plasticity of weeds and their greater intraspecific genetic variation compared with most crops could provide weeds with a competitive advantage in a changing environment. There is a possibility that agricultural weed populations will evolve new traits in response to emerging climate and non-climate selection pressures.

Impact of climate change in agriculture

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Agriculture is the backbone of Indian economy which in turn relies on the monsoon season. Rising global temperature is not only causing climate change but also contributing to the irregular rainfall patterns. Uneven rainfall patterns, increased temperature, elevated CO_2 content in the atmosphere are important climatic parameters which affects the crop production. The Intergovernmental Panel on Climate Change (IPCC) projected that the global mean surface temperature will likely rise and may result into uneven climatic changes. Climate change will compound the existing food insecurity and vulnerability patterns. Communities must prepare themselves for the possibility of food shortages and make appropriate use of resources to protect their livelihoods as well as lives and property. It is imperative to identify and institutionalize mechanisms that enable the most vulnerable to cope with the impact of climate change. This requires collaborative thinking and response to the challenges generated by the interaction between food supply, climate change and sustainable development. Though, the overall global impact of climate change on agricultural production may be small, regional vulnerabilities to food deficits may increase, due to problems of distribution and marketing of food to specific regions and groups of people. For subsistence farmers, especially for people who now face a shortage of food, lower yields may result not only in measurable economic losses, but also in malnutrition and even famine. C_3 photosynthetic pathways are expected to benefit more than C_4 from CO_2 enrichment. However, rising global temperature may give competitive advantage to C_4 plants than C_3. This differential response of C_3 and C_4 plants will alter crop weed interaction because of the fact that majority of weeds are C_4 and most of the food grain crops are C_3. Higher levels of carbon dioxide could stimulate the growth of some weed species and greater production of rhizomes and tubers in perennial weeds making them difficult to control. Climate models project that global surface air temperatures may increase by 4.0-5.8°C in the next few decades. These increases in temperature will probably offset the likely benefits of increasing atmospheric concentrations of carbon dioxide on crop plants. Carbon sequestration in agriculture and forestry as well as changes in land-use such as deforestation contributes respectively to 13 and 17% of total anthropogenic greenhouse-gas (GHG) emissions. Though the carbon dioxide emissions from agriculture are small, the sector accounts for 60% of all nitrous oxide mainly from fertilizer use and 50% of methane emitted mainly from natural and cultivated wetlands and enteric fermentation.

Cropping system's influence on shifts in weed flora under mid-hill conditions of Himachal Pradesh

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The cropping systems which have crops with different life cycles and management practices mainly influence the weed shifts. The present study was aimed at having an appraisal of weeds floristic diversity in rice based diversified cropping systems, tested under AICRP-IFS Palampur Centre at the Bhadiarkhar Farm of the university. Eight cropping systems, *viz.* C_1: 'rice – wheat', C_2: 'rice – pea – summer squash', C_3: 'okra– radish – onion', C_4: 'turmeric– pea – summer squash', C_5: 'rice – lettuce – potato', C_6: 'rice – palak – cucumber', C_7:'rice –broccoli– radish' and C_8: 'colocasia – pea + coriander', were evaluated for their production potential from *Kharif* 2014 to *Rabi* 2018. An appraisal of weed species associated with different cropping systems has been made during *Kharif* and *Rabi* 2016-17. *Ageratum* sp., *Cynodon dactylon, Commelina benghalensis* and *Monochoria vaginalis* were the major weeds found growing during *Kharif*. In *Rabi*, *Phalaris minor, Coronopus didymus* and *Spergula arvensis* were predominent weeds. In *Kharif* the broad-leafed weeds (BLWs) in all the systems had higher population than grassy weeds because of higher density of the *Ageratum* sp. (*A. houstonianum* and *A. conyzoides*), *Commelina benghalensis* and *Monochoria* sp. in the season. But on the other hand, in *Rabi* grasses had higher population than BLWs due to dominance of *Phalaris minor* in most of the systems. Population of grasses in *Kharif* was highest in 'turmeric – pea – summer squash' due to higher population of *Cynodon dactylon* in turmeric. Population of grasses in *Rabi*, mainly composed of *Phalaris minor*, was highest in 'rice – palak – cucumber' being at par with 'turmeric – pea – summer squash'. BLWs were present in highest number in 'okra– radish – onion' in both the seasons. In *Kharif*, highest population of BLWs in 'okra– radish – onion' was mainly composed of *Ageratum* sp. and remained at par with 'colocasia – pea + coriander' and 'turmeric– pea – summer squash' where colocasia (C_8) and turmeric (C_4) occupied the land. *Monochoria,* a weed of upland situations was only present in systems composed of rice in *Kharif*. In *Rabi,* highest number of BLWs was also in 'okra – radish – onion', mainly due to presence of *Coronopus didymus* and *Spergula arvensis* in higher amounts. Sedges were present in *Kharif* only. Highest population of sedges (*C. iria*, *C. difformis*, and *C. esculentus*) was in 'okra – radish – onion'. Total weed count in *Kharif* was highest in 'okra – radish – onion' due to higher number of BLWs and sedges associated with system and in *Rabi* the total weed count was highest in 'rice – palak – cucumber'. The appraisal of the weeds in different cropping systems clearly indicated their dynamism and inferred that their distribution is greatly influenced by management practices due to change in cropping systems. This clearly signifies the importance of cropping system or crop rotation approach to manage weed floristic diversity.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Influence of weather parameters on weed characters of winter irrigated cotton

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Cotton (*Gossypium hirsutum* L.) is cultivated in a wide range of climates and environments. These environments have a large impact on the growth, development, and quality of the crop. Environmental factors, some influenced by managing inputs and some not, will determine the crop's success by impacting plant growth and development, yield, and yield quality (Wells and Stewart 2010). Cotton, being a long duration, widely spaced and relatively slow growing crop during early growth stages, is subjected to severe weed menace. Weed infestation in cotton has been reported to offer severe competition and causing yield reduction to an extent of 40 to 85% (Sreenivas 2000). Cotton with minimal weed competition during the initial phase would yield better. Thus, there is need for selection of new molecules of pre-emergence herbicide to control weeds during initial crop period. Pendimethalin is now commercially available as 30% EC in market and with increase in active ingredient percentage, it is necessary to evaluate its effect on weeds and crops.

During winter 2008-09, broad-leaved weeds dominated the weed flora followed by grasses and sedges up to 60 DAS. Whereas, at 45 DAS, grassy weeds became dominant followed by sedges and broad-leaved weeds. Temperature and bright sunshine hours might be favourable for the growth of grassy weeds compared to broad-leaved weeds. During winter 2009-10, the temperature as well as relative humidity were favourable for the growth of broad-leaved weeds. Almost 53% of the field was completely covered with broad-leaved weeds which were observed up to 45 DAS. Whereas, at 60 DAS, the grassy weed density was dominant over sedges and broad-leaved weeds, possibly due to high temperature and solar radiation. At 120 DAS, all the weeds were suppressed due to shade effect of cotton and recorded comparable densities of grasses and broad-leaved weeds.

With regard to individual weed species, during winter 2008-09, the weather conditions favoured the growth of *Cynodon dactylon*, *Trianthema portulacastrum* and *Cyperus rotundus*. While during winter 2009-10, *Cynodon dactylon* was the dominant species followed by *Trianthema portulacastrum* and *Cyperus rotundus*. According to Gnanavel and Babu (2008), *Cyperus rotundus* L., *Cynodon dactylon* and *Trianthema portulacastrum* were the most common weeds which compete with cotton and could assimilate biomass faster than cotton. Similarly, *Trianthema portulacastrum* and *Echinochloa crusgalli* were the most dominant weeds in cotton as earlier reported by Balyan *et al.* (1983). Of the 14 weed species observed in the field, *Trianthema portulacastrum*, *Cyperus rotundus* and *Cynodon dactylon* were the major weeds that were found associated with cotton crop in the present study. This might be due to their inherent capacity for attaining faster growth which would have promoted the efficient utilization of growth factors such as solar radiation, light, moisture and nutrients which led to their dominance over other species of weeds. The weed survey conducted at Tamil Nadu has also indicated the dominance of *Trianthema portulacastrum* and *Cyperus rotundus* in cotton under gardenland conditions (AICRPWC, 1987).

Weed management in conservation agriculture

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Conservation agriculture (CA) technologies involve the three principles namely minimum soil disturbance, soil cover through crop residues or other cover crops and crop rotations. Zero-till (ZT) accomplish these principles and in India, it is mostly practised in north-western parts of the country (on more than 3 million ha area). But weeds can affect yields and sustainability of CA systems. The composition of weed species and their relative time of emergence differ between CA systems and conventional tillage systems. In ZT infestation of small seeded annual weeds increases initially due to the abundance of seeds at the surface of soil. However, in some places, adoption of zero tillage initially gave a good result but later on adoption declined due to increase in weed menace (Farooq *et al*. 2011). Therefore, for developing effective management strategies in CA system, understanding of ecology, seed bank and dynamics of specific weed flora is essential.

Furrow Irrigated Raised-Bed (FIRB) System is a form of reduced tillage that appears to overcome weed problems associated no-till systems (Chopra and Angiras 2008). Stale seedbed with two irrigations in combination with hand weeding recorded about 96.6% reduction in weed dry matter (Kumar *et al*. 2013). Soil incorporation of crop residue and their allelopathic interference reduces weed in the CA system. Zero-till sowing in standing crop residues along with application of herbicides in proper combination, sequence or in rotation leads to lower weed population and higher yield than conventional planting (Sharma and Singh 2014). For success of CA system, mechanization such as use of happy seeder, laser land leveller, robotic weed control methods are useful. Robotic weed control is new engineering tool to control weed mechanically and selectively, using flame or by herbicidal spray. Herbicide tolerant crop is an important biotechnological tool that contributes to weed management in CA system but, its use along with non-selective herbicide should not be considered as a single component of weed management. An integrated weed management strategy should be used to ensure that this tool remains profitable and environmentally sound over a long period of time.

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Major weeds of cropped and non-cropped areas at University seed farm, Nabha, Punjab

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The University Seed Farm (USF), Nabha is one of the important seed farms of Punjab Agricultural University (PAU). It is situated in the north-western part of India in Patiala district of Punjab. This farm is spread in an area of 493 acres. Out of 493 acres, about 410 acres are cultivatable and rest of the area is under buildings, paths, irrigation channels, drains *etc.* The USF, Nabha produces breeder, foundation, certified and truthfully labeled seeds of different field and vegetable crops. There is a great demand of seeds of varieties developed and released by PAU. USF, Nabha is engaged in production and distribution of over 1000 tonnes of seeds every year for the benefit of the farming community at state and national level. Major crops grown at the farm include cereals like are wheat, paddy, maize; pulses like summer moong, arhar; fodder crops like berseem, ryegrass, maize; oilseeds like raya, gobhi sarson; winter vegetables like radish, turnip, peas, tomato, methi; summer vegetables like cucumber, pumpkin, bottle gourd, bitter gourd, muskmelon, turmeric etc. Rice-wheat is major cropping system followed by maize-wheat and Sunhemp (green manuring)-peas-summer moong. It is well accepted that the knowledge of weed species associated with crops in a region is pivotal and obligatory to plan and execute a proactive weed management schedule depending upon various factors affecting weed distribution. USF Nabha was established in 2001 and weed flora at the farm has been in a state of dynamism brought by different factors. This farm is divided in six blocks based on similarity in the type of soils, irrigation water and fertility status. The type of irrigation, cropping pattern, weed control measures and management factors had a significant influence on the intensity and infestation of weeds. The present survey was conducted to study the abundance, distribution and diversity of weed flora in different field crops growing at the seed farm in different blocks. In rice-wheat cropping system, annual grasses like *Echinochloa colonum, Echinochloa crus-galli, Digitaria sanguinalis, Paspalum* spp. and sedges like *Cyperus* spp. are the major weeds during *kharif*. Weeds like *Phalaris minor*, *Rumex dentatus*, *Medicago denticulate* and *Melilotus indica* are very common in wheat fields. In maize-wheat cropping system, *Echinochloa colonum, Eleusine aegyptiacum, Cyperus rotundus* are major weeds where as *Digera arvensis, Trianthema portulacastrum* and *Scripus* spp. are minor weeds in maize. During *Rabi*, *Phalaris minor*, *Rumex dentatus, Medicago denticulate, Melilotus indica, Anagalis arvensis, Chenopodium album, Convolvulus arvensis, Fumeria parviflora* are the weeds infesting wheat crop in non-paddy fields. *Ipomoea* spp. is a relatively new weed infesting sunhemp, maize and summer moong crops. In non-cropped areas, the problem of *Parthenium hysterophorus, Datura stramorium, Calotropis procera, Corchorus tridens* and Alternanthera spp. infestation is common which require regular monitoring and management. Conclusively, the present survey document could be of much practical value in formulating management strategies.

Lantana camara: An emerging noxious weed in southern Rajasthan

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Lantana camara a weed of verbenaceae family native to American tropics , generally found on the roadsides, fallow and degraded lands was not a serious problem in southern Rajasthan till early 80's. But due to its wide dispersal rate and less attention to its management, now it is becoming a very serious problem in southern Rajasthan and is easily visible at many places on the road sides and degraded lands. It is very notorious and toxic weed that produce toxic chemicals which inhibit competing plant species and fatal to livestock and causing toxicity in them due to its pentacyclic triterpenoids. Not only it is harmful for livestock but also harmful for human being. Looking to the severity of infestation in the area it is the need of era that it must be managed in an integrated manner. The best and effective means of its control is by mechanical means which includes stick raking, bulldozing, ploughing and pulling (medium sized plants}. Hand cutting using brush cutters, hand pulling, chain pulling and flame weeding are also used. Re-growth will be imminent if the rootstock is not removed while weeding. Mechanical control is suitable only for small areas and is not recommended in areas susceptible to erosion. Fire is often used prior to mechanical or herbicidal control to improve their effectiveness or as a follow-up to such methods. For the chemical control of this weed during the active growing period, use of fluroxypyr 0.5 to 1 liter/100 liter water, glyphosate 1 liter/100 liter water and triclopyr 1 liter/60 liter of water is recommended. Post emergence application of glyphosate (2 kg/ha) may provide good control. Applications are to be done when there is good soil moisture and during the active growing period, either in the morning or late in the afternoon. Some of the biological species used to control *Lantana camara* are sap-sucking bug, *Teleonemia scrupulosa* (Hemiptera), leaf mining beetles, *Octotoma scabripennis* (Coleoptera) and *Uroplata girardi* (Coleoptera) and the seed feeding fly, *Ophiomyia lantanae* (Diptera). Apart from these agents, a sap-sucking bug, *Leptobyrsa decora*, a mealybug, *Phenacoccus parvus*, and a rust fungus, *Prospodium tuberculatum* are used in Australia for the biocontrol of Lantana. *Puccina lantanae*, a rust of tropical origin, is pathogenic to a wider range of weedy cultivars of Lantana. However, due to one or other reasons the use of biological method of controlling this weed is not found effective and popularizing. Hence, an integrated approach that uses a variety of control methods *i.e.* mechanical, chemical and biological methods gives best results to control this weed and at the same time the agronomists and extension workers may give proper attention towards its prevention and eradication through public and farmers participation by way of awareness camps and training programmes so that it may not further propagate and become a serious weed like *Parthenium*.

Role of agroforestry in mitigation and adoption of climate change

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Climate change has emerged as the leading environmental issue in the recent past. The cause of rapid climate change is primarilly attributed to two main reasons *i.e.* burning of fissils fuels and clearing of forests. Forest loss, mainly due to deforestation and degradation of forests, accounts for nearly 17% of global greenhouse gas emission. Forest trees play an important role in mitigation and adoption of climate change and act both as sources and sinks of greenhouse gases (GHGs).

Agroforestry is an ideal option to increase productivity of wastelands, increase tree cover outside the forest and reduce human pressure on forests under different agroecological regions and is also a viable option to prevent and mitigate change effects keeping all these facts in view, the present investigation has carried out to test the hypothesis on biomass production and crop production at the research form of Department of Forestry, Jawaharlal Nehru Krishi Vishwa Vidalaya, Jabalpur (M.P.) during the rainy season of 2012-13 and 2013-14 in 15 years old *Dalbergia Sissoo* plantation, Planted at a distance of 5 x 5 m. Fifteen treatment combinations were laid out in Split Plot Design comprised of 5 main treatments (P_0-No pruing, P_1 – 25 % pruing, P_2 – 50% pruing, P_3 – 75% pruing and open condition *i.e.* soil crop – no tree) and 3 dates of planting of turmeric crop (D_1 – 3rd week of June, D_2 – Last week of June, D_3 – Ist week of July) replicated four times. Under each treatment turmeric crop (variety - Surmoa) was planted at 20..Qtha at a planting geometry of 50 cm (Row to Row) X 15 cm (Plant to Plant). The crop was fertilized at 80:60:100 NPK kg/ha. The full quantity of phosphatic and potashic fertilizers along with half quatity of nitrogen were applied as basal and remaining quantity of N was top dressed into two spilit doses at 45 days after planting (first earthing) and 60 days after planting (second earthing). The growth and yield attributing charaters of turmeric and *Dalbergia Sissoo* were recorded as influenced by different pruning intensities and dates of planting of turmeric. The results revealed that planting of turmeric cv. Suroma with partial shaded condition *i.e.* 25 % pruning of tree gave maximum fresh rhizome yield (3314.6 kg/ha) when planted in the 3rd week of June and produced maximum growth and yield attributing characters as compared to open conditions. The highest net monetary return (` 80803/ha) was obtained under partial shaded conditions whereas, crop alone recorded the lowest monetary return (` 20144/ha). The maximum cylindrical volume (222.1/m^3 /ha) and above ground biomass (171.550 t/ha) were obtained in 25 % pruning intensity which was significantly superior to other pruning intensities while, these were the lowest in 75 % pruning.

Theme 2

Weed management in fruits, vegetable, and other high-priced crops

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Weed control methods for wetland paddy condition: A review

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Weeds are plants growing where they are not wanted. It interferes and competes with the main crop for their existence causing serious yield loss by sharing the land, water, nutrients, sunlight, and available CO_2 for the main crop. Grassy weeds, broad-leaf weeds, and sedges are main weeds present in the paddy field. The major weeds of paddy crop were *Echinochloa colona* (Jungle rice), *Echinochloa crus-galli* (Common barnyard grass), *Chloris barbata* (swollen windmill grass), *Cynodon dactylon* (Bermuda grass), *Centella asiatica* (Gotu kola) and *Cyperus difformis* (Sedge). During early establishment, the weeds make 20-30% of their growth while the crop makes 2-3% of its growth. Weeding accounts for about 25% of the total labor requirement of paddy crop. It is estimated that reduction in yield due to weeds alone is 20–30% depending on the crops, weed infestation intensity and location, which might increase up to 50% if adequate crop management practices were not observed. Various common weed control methods are manual, mechanical, chemical and biological. Manual weeding can give a clean weeding, but it is a very slow process. It has been reported that the time required to weed one hectare of land is in the range of 300 to 320 man/h. Chemical weeding method is responsible for environmental pollution, reduction of micro organism population during the crop season and accumulation of herbicidal residue in the produce. The mechanical weeding either by hand tools or mechanical weeders is the most effective method both in dry and wetland paddy. Mechanical weed control not only uproots the weeds between the crop rows but also keeps the soil surface loose, ensuring better soil aeration and water intake capacity. To get the full benefit of mechanisation, it is required to use appropriate weeding implements, which will reduce drudgery and cost of cultivation. As on today, many types of manually operated tools such as Cono weeder, Mandwa weeder, and Japanese paddy weeders have been developed and used for weeding in lowland paddy. One of the major constraints in using manually operated weeders is the high physical effort that is needed to push the weeder in the wet and highly resistant soil. The push type Cono-weeders are difficult to use as these have to be moved back and forth and do not work well under conditions of highly dried soil, high inundation of flood water and at the existence of bigger sized weeds. Power weeders on the other hand have higher field capacity and less operator drudgery. Power weeders like Garuda paddy power weeder, and Japanese power weeder which are available in the market.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Weed management in onion under east and south eastern plain zones of Odisha

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Onion is one of the important commercial vegetable crops grown in India. Due to its slow growing, shallow rooted, narrow and upright leaves; onion crop is severely affected by weed competition at initial period of the crop growth. Though some pre-emergence herbicides can able to control the weeds at initial period of crop growth, there is a very limited options available to control the successive flushes of weeds in onion. The conventional methods of manual weeding are very laborious, expensive and cumbersome. Hence, using good herbicide at right time is one of the suitable options not only to manage the weed problems in onion in an effective and economic manner but also helps in utilizing those labours in a more productive alternate ways for profit optimization. Considering these facts an attempt has been made to manage weeds by using some new molecules in onion. A field experiment was conducted at Central farm, Orissa University of Agriculture and Technology, in onion with 7 weed control treatments in a randomized block design with three replication during *Kharif* seasons of 2016. The geo spatial position of the site was located at 200 15' N latitudes and 850 52' E longitudes with an elevation of 25.9 m above MSL. The climate is hot and humid with mean annual rainfall of 1467 mm. The soil of experimental field was sandy loam with pH 6.5, organic carbon 0.41%, available N 175 kg/ha, P_2O_5 26 kg/ha and K_2O 215 kg/ha. The variety 'Dark Red' of onion, was transplanted in the month of September during 2016 at a spacing of 30 x 10 cm. Pendimethalin (33%) was applied 2 days after transplanting as pre-emergence (PE), quizalofop-p-ethyl (4%) + oxyfluorfen (6%) (RM) was applied 15 days after transplanting as early post-emergence (EPoE), while oxyfluorfen (23.5%), quizalofop-p-ethyl (5%), propaquizafop (10%) were applied 25 days after transplanting as post-emergence (PoE) when weeds were at 3—4 leaf stages as per the treatments. The manual weeding was done at 20 and 40 DAT. Weed density and dry weight of weeds were recorded at 30, 60 and 90 days after transplanting (DAT) by using a quadrat of 0.5 x 0.5 m randomly from three places in each plot. The floral composition of different weed species of the experimental sites were *Ludwigia parviflora*, *Celosia argentea*, *Cleome viscose*, *Physalis minima* among major broad-leaved weeds, *Cynodon dactylon*, *Eluesine indica*, *Digitaria sanguinalis* among grasses and *Cyperus rotundus* among sedges. Basing on the result analysis, it was concluded that application of ready mix combination of oxyfluorfen + quizalofop-p-ethyl (RM)100 g/ha is the most effective herbicide in controlling the complex weed flora in onion with WCE (78%), resulting in higher bulb yield (20.6 t/ha) with maximum benefit cost ratio (2.37).

Integrated weed management in *Kharif* onion

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A field investigation on "Integrated weed management in *Kharif* onion (*Allium cepa.,* L)" was conducted during *Kharif*, 2015 at AICRP on Irrigation Water Management Project Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharastra). The experiment was laid out in RBD with three replications. The soil was clayey in texture, low in available nitrogen, medium in available phosphorus and very high in potassium with pH 7.8. The onion seedlings were transplanted at distance of 15 x 10 cm. The fertilizer dose applied was 100:50:50 N, P_2O_5 and K_2O kg/ha. Herbicides were sprayed as per the treatments. The weed flora observed in experimental field was *viz. Cyperus rotundus* L., *Cynodon dactylon* L., *Parthenium hysterophorus* L., *Echinochloa crus-galli* L., *Amaranthus spinosus L., Digera arvensis* Forsk., *Euphorbia geneculata* L., and *Convolvulus arvensis* L. Weed free check recorded significantly lowest total weed count and weed dry matter at harvest as compared to rest of the treatments except treatments post-emergence (PoE) application of tank mix oxyfluorfen 23.5% EC + quizalofop-ethyl 5% EC (88.13 + 25 g/ha) at 25 DAT, ready-mix of propaquizafop 5% + oxyfluorfen 12% (43.75 + 87.5 g/ha) at 25 DAT, tank mix of oxyfluorfen 23.5% EC + propaquizafop10% EC (87.5 + 43.75 g/ha)at 25 DAT and three HW at 15, 30 and 45 DAT. Significantly higher weed control efficiency and minimum weed index were observed with weed free check *fb* PoE application of tank mix oxyfluorfen 23.5% EC + quizalofop-ethyl 5% (88.13 + 25 g/ha) at 25 DAT, ready-mix propaquizafop 5% + oxyfluorfen 12% (43.75 + 87.5 g/ha) at 25 DAT, tank mix oxyfluorfen 23.5% EC + propaquizafop 10% EC (87.5 + 43.75 g/ha) at 25 DAT and three HW at 15, 30 and 45 DAT. While the highest herbicide efficiency index (HEI) values were rest with PoE application of tank mix oxyfluorfen + quizalofop-ethyl 5% EC (88.13 + 25 g/ha) at 25 DAT (2.92), ready mix propaquizafop 5% + oxyfluorfen 12%) (43.75 + 87.5 g/ha) at 25 DAT (2.43) and tank mix oxyfluorfen 23.5% EC + propaquizafop 10% EC (87.5 + 43.75 g/ha) at 25 DAT (2.33). Weed free check recorded significantly highest onion blub yield (24.23 t/ha) than other treatments but it was comparable with the treatment PoE application of tank mix oxyfluorfen + quizalofop-ethyl 5% EC (88.13 + 25 g/ha) at 25 DAT (23.44 t/ha). Significantly higher net monetary returns was obtained from PoE application of tank mix oxyfluorfen 23.5% EC + quizalofop-ethyl 5% EC (88.13 + 25 g/ha) at 25 DAT (` 1,14,939/ha) but it was at par with PoE application of ready mix propaquizafop 5% + oxyfluorfen 12% (43.75 + 87.5 g/ha) at 25 DAT (` 1,11,479/ha), tank mix oxyfluorfen 23.5% EC + propaquizafop 10% EC (87.5 + 43.75 g/ha) at 25 DAT (` 1,08,457/ha). Whereas, maximum B-C ratio (2.89) was observed with PoE application of tank mix oxyfluorfen 23.5% EC + quizalofop-ethyl 5% EC (88.13 + 25 g/ha).

Bio-efficacy of different herbicides on growth and productivity of onion

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The present investigation entitled Bio-efficacy of different hebicides on growth and productivity of onion cv.*'N-53*' was conducted during two consecutive years 2016 and 2017 at vegetable research farm, SKUAST-J, Chatha. The experimental site was located 32^0-40^0 N latitude and 74^0-53^0 E longitude at a height of 300 meters above mean sea level at a distance of 15 km from the main city of Jammu. The experiment was laid out in randomized block design with three replications and fourteen treatments. The gross plot size was 6.0 sq.m where as net plot size was 3.8 sq.m. The seedlings were planted at a spacing of 20 x 10 cm. Pendimethalin (1.0 kg/ha) and oxyflurofen (0.15 kg/ha) were applied 2 days before transplanting as pre-plant and 2 days after transplanting as pre-emergence. Alachlor (1.5 kg/ha) and butachlor (1.0 kg/ha) were applied at 2 days after transplanting of the seedlings. Quizalofop-ethyl (0.05 kg/ha) was applied in combination with above 4 herbicides as post-emergence 40 DAT. These herbicides were sprayed by hand sprayers of 1 litre capacity using 600 litres of water per hectare. The weed density, weed dry matter accumulation and weed control efficiency varied significantly with the stages of the crop. Considering the weed control strategies, significantly lower weed density, weed dry matter accumulation, weed index and relatively higher weed control efficiency were recorded in weed free plots *fb* treatment with pre-emergence application of oxyflurofen 0.15 kg/ha+ 1 HW 40-60 DAT, which was at par with pre-emergence application of quizalofop-ethyl 0.05 kg/ha applied at 40 DAT. Among the treatments, the weed free plots produced plants with less neck thickness (1.03 cm.), higher average bulb weight (84.10 g), bulb yield/plot (10375.03 g), total soluble solids (14.38^0 Brix) and sulphur content (9.78 moles pyruvate/g). It was followed by pre-emergence application of oxyflurofen 0.15 kg/ha *fb* post-emergence application of quizalofop-ethyl at 0.05 kg/ha applied 40 DAT. The phytotoxicity symptoms of herbicides on crop were negligible. From economics point, the weed free plots resulted in higher cost of cultivation and net returns but lower B-C ratio whereas in pre-emergence application of oxyflurofen at 0.15 kg/ha *fb* post-emergence application of quizalofop-ethyl at 0.05 kg/ha applied 40 DAT showed highest B-C ratio.

Efficacy of different pre- and post-emergence herbicides and cultural methods of weed management in turmeric

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Due to improper weed management, 30-70% yield losses have been reported in turmeric. The field experiment was conducted during *Kharif* season of the year 2016-17 at the research farm of AICRP on Weed Management, Agronomy Department, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) in randomized block design with three replication having fourteen different chemical and integrated weed management treatments compared with cultural weed management and unweeded check. The different pre-emergence herbicides *viz*. metribuzin, pendimethalin, atrazine, oxyflurofen *etc.* were tried in combination with cultural practice. The turmeric variety PDKV Waigaon was planted at the spacing of 45 x 22.5 cm on 27thJune 2016 with recommended dose of fertilizer 200:100:100 kg NPK/ha. The major weed flora during *Kharif* season in turmeric crop in the selected area composed of both broad and narrow-leaved weeds, however, dominance of broad-leaved weeds like *Xanthium strumarium, Celosia argentea, Tridax procumbens, Phyllanthus niruri, Lagasca mollis, Euphorbia geniculate, Euphorbia hirta, Phyllanthus niruri, Alternanatheratriandra, Parthenium hysterophorus, Digera arvensis* were observed in entire field.

The results revealed that, among different weed management treatments, hand weeding at 25, 45 and 75 DAP recorded significantly lower weed count, dry matter accumulation and WCE of 94.9% followed by integrated weed management treatments of metribuzin 0.7 kg/ha PE followed by straw mulch 10 t/ha *fb* one HW which recorded lowest weed population and weed dry weight at harvest and WCE of 58%, followed by pendimethalin 1 kg/ha (0-5 DAP) *fb* straw mulch 10 t/ha (10 DAP). Lowest weed index (4.8) was recorded in treatment pendimethalin 1 kg/ha (0-5 DAP) *fb* straw mulch 10 t/ha (10 DAP) *fb* one HW (75 DAP) followed by metribuzin 0.7 kg/ha (0-5 DAP) *fb* straw mulch (10 DAP) *fb* HW (4.96) followed by atrazine 0.75 kg/ha (0-5 DAP) *fb* straw mulch (10 DAP) *fb* HW (6.12). Maximum rhizome yield was observed in weed free treatment (22.78 t/ha), while among the IWM treatments application of pendimethalin 1 kg/ha (0-5 DAP) *fb* straw mulch 10 t/ha (10 DAP) *fb* one HW recorded higher rhizome yield (21.69 t/ha). Due to higher rhizome yield, highest monetary returns of ` 2,76,782 was registered under pendimethalin 1 kg/ha (0-5 DAP) *fb* straw mulch 10 t/ha *fb* one HW with B:C ratio of 4.16 followed by metribuzin 0.7 kg/ha *fb* straw mulch (10 DAP) *fb* HW with NMR of ` 2,74,266 and B:C ratio of 4.06 highest than the hand weeding (25, 45 and 75 DAP) (3.11). Thus, it can be inferred that, integrated use of either pendimethalin 1 kg/ha or by metribuzin 0.7 kg/ha (0-5 DAP) *fb* straw mulch 10 t/ha (10 DAP) *fb* one HW (75 DAP) was adjudged very effective for weed control and for attaining the highest productivity and profitability in turmeric.

Weed dynamics in elephant foot yam and sweet potato grown under rainfed conditions of Konkan region of Maharashtra

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Weeds are ubiquitous and continue to be an important constraint in the production of root and tuber crops owing to the initial slow growth of these crops. Sweet potato and elephant foot yam are majorly cultivated in *Konkan* region of Maharashtra. The investigations were carried out in consecutive seasons of *Kharif* 2016 and 2017 at AICRP on Tuber Crops, Central Experiment Station, Wakawali, to study the weed dynamics in elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson] and sweet potato (*Ipomoea batatas* L.) crops. The results revealed that, the elephant foot yam was infested mainly with BLWs like *Alternanthera sessilis*, *Physalis minima*, *Phylanthus niruri*, *Isachne globosa*, *Vernonia cineria*, *Amaranthus viridis*, *Desmodium trifolium* and *Urena lobata*. Amongst these, *Alternanthera sessilis*, *Physalis minima*, *Phylanthus niruri* and *Isachne globosa* were the predominant BLWs. The different grasses and sedges noticed were *Eleusine indica*, *Eragrotis minor*, *Echinochloa colona*, *Echinichloa crusgalli* and *Cyperus rotundus*. Among grasses *Eleusine indica*, *Echinichloa colona*, *Eragrostis minor* were more rampant while in sedges *Cyperus rotundus* was predominant. Among different fertilizer levels tested, the total weed density (4.54 and 6.79 no./m^2) and biomass (2.24 and 3.21 g/m^2) were found significantly highest under the higher fertilizer level (125% RDF) as compared to lower fertilizer levels (75% and 50% RDF) and remained at par with 100% RDF at early stages *i.e.* two and four months after planting.

Under sweet potato crop, the BLWs observed were *Alternanthera sessilis, Borreria pusilla, Amaranthus viridis, Desmodium triflorum, Urena lobata, Urena sinuate, Euphorbia hirta, Ludwigia parviflora, Commelina benghalensis, Commelina diffusa, Murdannia nudiflora, Mimosa pudica, Mitracarpus villosus, Mollugo nudicaulis, Mollugo pentaphylla, Phyllanthus niruri, Phyllanthus urinaria, Stellaria media.* Amongst these *Phylanthus niruri*, *Mollugo pentaphylla* and *Mollugo nudicaulis* were the predominant BLWs. The different grasses and sedges noticed were *Eleusine indica*, *Eragrostis minor*, *Echinochloa colona*, *Echinochloa crusgalli, Cynodon dactilon, Brachiaria erusiformis, Brachiaria ramose, Digitaria sanguinalis, Eriocaulonsie boldianum, Isachaemum globosa, Cyperus rotundus, Cyperus brevifolius,* and *Cyperus compressus*. Among grasses *Eleusine indica*, *Echinochloa colona*, *Eragrostis minor* were more rampant while in sedges *Cyperus rotundus* was predominant. Among the different planting times, the total weed density (12.6/m^2) and biomass (6.27 g/m^2) was found significantly highest under early planting (24^{th} Met.Week) as compared to late plantings at 30 days after planting. Numerically, higher values of weed density and biomass were found in higher nitrogen level (100 kg N/ha) and full basal dressing of nitrogen as compared to lower nitrogen levels (75 and 50 kg N/ha) and split application of nitrogen as 50% basal and 50% top dressing at 30 days after planting.

Hence, it can be concluded that, in *Konkan* region under rainfed conditions, the Elephant foot yam and sweet potato crops were mainly associated with BLW like *Phylanthus niruri*, grasses like *Eleusine indica*, *Echinichloa colona*, *Eragrostis minor* and *Cyperus rotundus* amongst sedges.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Weed management for cut flowers

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Weeds compete for water, nutrients and light resulting in reduced flower yield and increased threat of serious insect and disease problems. A successful weed management program utilizes cultural practices such as cultivation and mulching, or a combination of cultural and chemical measures, taking into consideration labor costs and the cost and availability of materials. Weed management begins with a survey of the site. Weeds should be identified and the level of weed pressure noted. Weeds can be classified according to their life cycles. Knowing the weed life cycle is important in determining the optimal timing for cultural management practices or herbicide applications. Summer annuals emerge in the spring, flower, and set seed before the first frost. In cultivated fields, summer annuals tend to predominate as the primary weed type. Winter annuals germinate at the end of the summer or early fall, over winter, then flower and fruit in the summer. Biennials need at least two seasons to complete their life cycle and, like annuals, biennials die after flowering. Perennials, which survive more than two seasons, can propagate by seed or vegetatively. Vegetative reproductive organs such as tubers, rhizomes (underground stems), stolons (above ground creeping stems), bulbs and corms, are often resilient to both cultural and chemical control measures and should be targeted for control before planting the field. It is also important to scout weed populations during and after the growing season in order to assess the success of the weed control program. Herbicides are available that may be safely used to control weeds in cut flowers. However, in many situations herbicides cannot be used or are not effective in controlling all the weeds. Even if effective herbicides are available, growers should utilize cultural practices that reduce weed infestations and spread. A mulch is a layer of material applied to the surface of soil. Reasons for applying mulch include conservation of soil moisture, improving fertility and health of the soil, reducing weed growth and enhancing the visual appeal of the area. A mulch is usually, but not exclusively, organic in nature. Mulches can effectively control most annual weeds from seed. According to Dr. Andrew Senesace of the Long Island Research Laboratory, black plastic or a geotexitile fabric such as Weed block can control most annual weeds around field grown herbaceous perennials. In some studies however, due to the physical restriction of the spreading shoots, these mulches reduced *Achillea* and *Stachys* flower production.

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Weed management in vegetable crops

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The vegetable field are usually infested by a wide spectrum of broad-leaved and grassy weed which reduce the yield by competing for moisture nutrient and light during the growing season weed also harbor insects pathogen and interfere with harvesting and also lower the quality of crop seed by mixing with them thus if weed control is not carried out timely the reduction in yield will be more the research conducted at various agro climatic reason of India evinced that vegetable are more sensitive to early weed competition which substantially reduce vigorous uniformal and the overall yield thus accentuating the weed control at early crop stage the critical period of weed competition is usually longer in direct seeded vegetable than in transplant crop this includes a combination of management practices, *viz.* crop rotation cover cropping high panting density mulching inter cultivation flooding and herbicide use designed to suppress the weed. The vegetable crop are poor competitor because of the slow growing nature and wider spacing. Tomato: requires frequent shallow cultivation especially during the first four week after transplanting. The improper weed management can cause the yield loss 40-60%. Brinjal: mulching with sugarcane trash on 18 days after transplanting reduce the infestation of weed bar averting light from reaching the weed. Potato: the agro techniques adopted for potato provide favourable condition for early germination and establishment of weeds well before the potato crop emerge the most critical period for crop weed competition is from 2-6 weeks after planting. Mulching can be done by the use of polythene films, drystraw, grasses and other plant parts for controlling weed. Pendimethalin at 1.0 kg/ha is applied as pre planting and incorporated in the soil but it can also be used as pre-emergence. Cauliflower: The problem of weed completion is more in Cauliflower which reduces the curd yield by 36-50%. This is due to wider spacing, frequent irrigation and more usage of manure and fertilizers. Use of black polyethylene film, mango leave, pine needles and straw as mulch help in suppressing the weeds. Fluchloralin at 1.2 kg/ha as pre-planting herbicide Nitrofen at 2.0 kg/ha.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Integrated weed management in carrot

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Vegetables play an important role in human nutrition. The biggest challenge in the country is to provide food and nutritional security. Carrot (*Daucus carota* L.) is an important vegetable crop grown in spring, summer and autumn in temperate regions and during winter in tropical and sub-tropical regions and an excellent source of carotene, a precursor of Vitamin-A. The losses caused by weeds exceed the losses from any other category of agricultural pests. Therefore, an experiment was conducted to study the efficacy of different herbicides and their integration in Randomized Block Design replicated thrice comprising fourteen weed management practices *viz.*, Pendimethalin C.S. 0.75 kg/ha as PE, pendimethalin C.S. 0.75 kg/ha as PE followed by quizalofop ethyl 50 g/ha as POE at 30 DAS, pendimethalin C.S. 0.75 kg/haas PE followed by propaquizafop 75 g/ha as POE at 30 DAS, pendimethalin C.S. 0.75 kg/ha as PE as followed by hand weeding (30 DAS), metribuzin 70 WP 0.3 kg/ha as PE, metribuzin 70 WP 0.3 kg/ha as PE followed by quizalofop ethyl 50 g/ha as PoE at 30 DAS, metribuzin 70 WP 0.3 kg/ha as PE followed by propaquizafop 75 g/ha as POE at 30 DAS, metribuzin 70 WP 0.3 kg/ha as PE + one hand weeding at 30 DAS, pendimethalin 0.75 kg/ha as PE, pendimethalin 0.75 kg/ha as PE followed by quizalofop ethyl 50 g/ha as POE at 30 DAS, pendimethalin 0.75 kg/ha as PE followed by propaquizafop 75 g/ha as POE at 30 DAS, pendimethalin 0.75 kg/ha as PE followed by hand weeding (30 DAS), hand weeding at 30 and 60 DAS, and unweeded control.

The weed flora consisted of *Cyperus rotundus* L. among sedges and among the grasses *Cynodon dactylon* L., *Digitaria sanguinalis* L. and *Echinochloa crusgalli* L.Beauv were predominant. Among broad-leaved weeds (BLWs) *Parthenium hysterophorus* L., *Digera arvensis* Forsk, *Trianthema portulacastrum* L. and *Amaranthus viridis* L. were the major weeds. Weed density, weed dry matter were least and weed control efficacy was highest in the treatment which received metribuzin (PE) 0.5 kg/ha + hand weeding at 30 DAS. Herbicides and their combinations significantly reduced the population of grasses and broad-leaved weeds. Whereas, sedges were effectively controlled by hand weeding only.

Herbicides, their combinations and their integration with hand weeding produced significant differences in growth parameters, yield components and yield of carrot crop. The yield was inversely related to weed infestation. Among all the weed control treatments highest yield was recorded with metribuzin (PE) 0.3 kg/ha + hand weeding at 30 DAS which was on par with farmers practice of hand weeding at 30 and 60 DAS and unweeded control registered lowest yield.

Among the different integrated weed management practices the net returns (` 162900/ha) and B: C ratio (2.38) were significantly higher with the PE application of metribuzin 0.3 kg/ha + hand weeding at 30 DAS. This indicated that the integrated approach of weed management is most beneficial as compared to herbicides alone in carrot.

Plastic mulch play vital role for control of weeds in vegetable crop production

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Many vegetable crops, like onion, garlic ginger, cucumber *etc*. cultivation has several constraints in production, of which weeds often pose a serious problem by competing for space, light, water and nutrients, weakening crop stand and reduce harvest efficiency. 90% yield losses in vegetable due to weeds. Weeds may harbor insect and disease organisms that attack vegetables and other crops. *For example:* Carrot weevil and carrot rust fly may be harbored by the wild carrot, to later pose a problem for cultivated carrots. Aphids and cabbage root maggots may live in wild mustards to later attack cabbage, cauliflower, radish and turnips. Thrips thrive in ragweed and mustards, and may later attack vegetable crops. The virus diseases, squash leaf curl on watermelon and spotted wilt of tomatoes are carried by insect vectors that live on weeds in fields and along field borders. All types of vegetables and other crop products may be reduced in quality, rendering them less marketable. Weeds can cause vegetables to be spindly, poorly developed and colored "leafy crops;" root crops can become poorly formed; fruits (tomatoes, peppers, beans) undersized, low quality, and poorly shaped. The losses due to weeds depend upon type of weed flora, their density, agro-climatic conditions, fertility, moisture status, soil type and type of growth of the crop etc. Though manual weeding is the effective method of weed control, it is cumbersome and uneconomical due to hike in wages and labour scarcity in these days. Mulches are effective alternatives to herbicides, and there are several materials commonly used. Studies have found that mulch treatment is effective for increasing soil moisture and temperature, which hastens earlier fruit maturity. Early germination has also been observed with the application of black polyethylene as well as increased agricultural yields. Mulching is a non-chemical weed control crop production technique that involves placement of organic or inorganic materials on the soil surface so as to provide a more favourable environment for plant growth and development. This in turn may affect plant growth and yield. Black polythene mulch was effective totally in suppressing weed growth. Lesser weed germination and weed infestation by restricting the penetration of solar radiation under black polythene mulch resulted in higher weed control efficiency. The lowest weed index was observed in the treatments black polythene mulch due to suppression of all types of weeds at critical periods. Similar results were reported by, Sha and Karuppaiah 2005 in brinjal and Choudhary *et al.* 2012 in capsicum.

Integrated weed management practices in turmeric under *tarai* region of Uttarakhand

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Turmeric (*Curcuma longa* L.) is one of the most valuable spices all over the world. It is a herbaceous perennial plant belonging to the family Zinziberaceae. In the present scenario, India is the world's largest producer of turmeric but its average productivity is quite low, mainly due to the competition offered by weeds which reduce yield by 30-80%. Late emergence, slow initial growth, wider spacing and poor canopy development provide an ideal environment for weeds to grow and compete with the crop. The experiment was conducted at Vegetable Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India during *Kharif* 2015. The soil of experimental site was silty clay loam having 7.4 pH, 0.70% organic carbon, 286.8, 26.6 and 268 kg/ha available N, P_2O_5, and K_2O, respectively. The experiment consisted of 15 treatments *i.e.* metribuzin 0.7 kg/ha PE *fb* 2 hand weeding (HW) at 45 and 75 DAP, metribuzin 0.7 kg/ha PE *fb* fenoxaprop 67 g/ha + metsulfuron methyl (MSM) 4.0 g/ha at 45 DAP, metribuzin 0.7 kg/ha PE *fb* straw mulch at 10 t/ha *fb* HW at 75 DAP, pendimethalin 1.0 kg/ha PE *fb* 2HW at 45 and 75 DAP, pendimethalin 1.0 kg/ha PE *fb* fenoxaprop 67 g/ha+ MSM 4.0 g/ha at 45 DAP, pendimethalin 1.0 kg/ha PE *fb* straw mulch at 10 t/ha *fb* HW at 75 DAP, atrazine 0.75 kg/ha PE *fb* 2 HW at 45 and 75 DAP, atrazine 0.75 kg/ha PE *fb* fenoxaprop 67 g/ha + MSM 4.0 g/ha at 45 DAP, atrazine 0.75 kg/ha PE *fb* straw mulch 10 t/ha *fb* HW at 75 DAP, oxyfluorfen 0.30 kg/ha PE *fb* 2 HW at 45 and 75 DAP, oxadiaragyl 0.25 kg/ha PE *fb* 2 HW at 45 and 75 DAP, glyphosate 2.5 L/ha at 25 DAP *fb* 2 HW at 45 and 75 DAP, glyphosate 3.7 L/ha at 25 DAP *fb* 2HW at 45 and 75 DAP, three hand weeding at 25, 45 and 75 DAP (3 HW), control. The result indicated that application of pre-emergence herbicides (atrazine 0.75 kg/ha, metribuzin 0.7 kg/ha and pendimethalin 1.0 kg/ha) *fb* straw mulch at 10 t/ha supplemented with one hand weeding at 75 days after planting treatments for weed control in turmeric are the best options.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Effect of soil applied herbicides on bio-efficacy and phytotoxicity on Cardamom, Coffee and Pepper seedlings

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Weed management is one of the important factor responsible for low productivity in spice crops, *viz.* Coffee, Cardamom and Pepper, which are commonly growing perennial spice crops in hill zone of Karnataka. The crops are sciophytes requires minimum of fifty per cent of shade for their normal growth and development. Due to heavy rains during rainy season the crops suffers from weed manace. The major cost of production involves weed management. Hence an experiment was conducted at Zonal Agricultural Research Station, Mudigere, Chikmagalur district of Karnataka to know the effect of soil applied pre-emergent herbicides, *viz.* pendimethalin, butachlor, alachlor and atrazine on bio efficacy and phytotoxic effects on Coffee, Cardamom and Pepper plants. Seedlings of crops were grown for one year in Polythene bags (33 x 15 cm) filled with soil and three plants per herbicide dose treatment were maintained as three replications. Fifty seeds of major weed species (broad-leaf) namely, *Bidens pilosa*, *Ageratum conyzoides* and *Crossocephalum crepidioides* were incorporated in polythene bags. Three days after sowing of weed seeds, different concentrations of herbicides, *viz.* pendimethaline at the rate of 250, 500, 1000 and 2000 g/ha, butachlor, atrazine and alachlor at the rate of 312, 625, 1250 and 2500 g/ha were sprayed on soil surface of weed seed sown polythene bags. The phytotoxic effects of applied herbicides on crops were photo documented at 21 days after application. The germinated weed seeds were taken out from polythene bag and weed biomass (g) was recorded. The data indicated that atrazine significantly reduced weed population compared to other soil applied herbicides in all the selected crops. Herbicides butachlor at the rate of 0.5 kg/ha and alachlor at the rate of 1.25 kg/ha are proved to be more effective than pendimethalin. However atrazine cause phytotoxicity in coffee, cardamom and pepper crops. The symptoms like yellowing of leaf petiole, followed by leaf abscission were observed in coffee seedlings. In pepper elongation of leaf petiole and leaf bending was observed in all atrazine treated seedlings, whereas in cardamom seedlings, atrazine treated plants showed typical symptoms of phytotoxicity. At the base of cardamom seedling (A junction between stem and root) swollen stem and complete horizontal bending of stem was noticed in all the concentrations of atrazine. Weed growth suppression was not observed in pendimethalin treatment compared butachlor or alchlor. There was no phytotoxicity of these three herbicides even at higher concentration. Application of butachlor at the rate of 0.5 kg/ha was effective in controlling weeds in coffee and cardamom crops without any phytotoxic effects and alachlor at the rate of 1.25 kg/ha was found to be effective in reducing weed population in pepper crop.

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Weed dynamics in medicinal and aromatic plants and their management in Chhattisgarh

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India has been identified as one of the twelve mega-bio-diversity centres of the world with immensely rich medicinal and aromatic plants occurring in diverse eco-systems. Medicinal plants form a large group of economically important plants, which provide the basic raw materials for the indigenous pharmaceutical industry and also help the country to earn foreign exchange. In the present time, the medicinal and aromatic plants and their various products are looked upon not only as a source of affordable health care, but also as an important commodity item of international trade. Medicinal and aromatic plants are infested with a number of weed species which not only reduce the production but hampers the quality also. Majority of weeds occur belong the division of angiosperms which includes dicotyledones (dicots) and Monocotyledones (monocots). Monocots include the grasses, sedges, nuts *etc.* There are approximately 200 species occur as weed and 51 of these species comprised of troublesome weed. About 70% weeds of 200 species belong to 12 families. The weeds which infest the medicinal and aromatic plants are annuals, biennials and perennials according to their life cycle. Majority of weeds grow in medicinal plants are annual, besides, some perennial weed also grow and difficult to manage because many perennial weed spread. Weeds and their population density often changes as a result of selection pressure of weed control practices followed, *i.e.*, herbicide use, tillage, cultivation, grazing and cropping sequence changes. Use of herbicides has altered the species composition of cultivated lands probably more than any other single production activity. Likewise, changes is rotational and tillage practices may greatly impact species composition and population density. The persistence of annual species is generally favoured by tillage that continually makes the ideal condition favourable for seed germination and establishment in comparison to untilled land. Among the losses caused by different pests in agriculture, the weeds account of about 40% and it may be more or less equal in the case of medicinal plants.

The high yielding varieties of medicinal and aromatic plants for example in the crops of Ashwagandha and Chandrasur, are responsive to chemical fertilizers and irrigation and the new intensive cropping systems have led to new weed problems which cause enormous loss.

This study reveals the number and diversity of weeds occur in medicinal and aromatic plants along with critical period in major medicinal and aromatic crops grown and their management in Chhattisgarh plains.

Assessment of effect of different mulch materials on weeds in summer tomato in farmers' field West Bengal

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Tomato is one of the most important vegetable crops mainly grown in *Rabi* season in West Bengal where climate is tropical humid and winter is short lived. Though, there are some new varieties which perform well during spring-summer season (January-April) in West Bengal, but while growing in this period, weed infestation at initial crop growth stage is a major problem for its successful cultivation. During this season, the major weeds in tomato fields are *Solanum nigram, Physalis minima, Chenopodium album, Melilotus alba, Fumaria parviflora, Anagalis arvensis, Cirsium arvense, Cucumis* spp., *Ageratum conyzoides, Amaranthus* spp., *Cyperus esculentus*, *C. rotundus, Leersia hexandra, Digitaria sanguinalis* and *Cynodon dactylon*. To overcome this problem, a field experiment was carried out as on-farm trail (OFT) during 2016 and 2017 in farmers' fields of Hooghly district to assess the efficacy of different mulch materials to manage different weeds in tomato field and also its effect on yield. The experiment was laid out in a Complete Randomized Block Design with seven replications and the experimental site comes under subtropical humid region. The average temperature ranges from 25-37ºC during summer months. The soil of the experimental field was clay loam having high water holding capacity with pH around 6.5. The tomato variety taken was 'Tanuja' which is a promising high temperature tolerant variety. Three technology options were taken during the trial *viz.* black/ silver plastic, straw and jute non-woven agricultural fabric along with farmer's practice *i.e.* no mulch (control). The results showed that black/silver plastic mulch suppressed weed growth up to 97% than unmulched field at 50 DAT. The highest number of weeds including grasses and broad-leaf weeds population/m^2 were 140 and 385.8 and weeds dry weight were 2.32 g/m^2 and 7.76 g/m^2 for 30 and 50 DAT, respectively recorded in control plots followed by straw and jute mulches and the lowest was in black/silver plastic mulch (weed population were 1.6 and 11.15/m^2 and dry weight were 0.08 g/m^2 and 1.07 g/m^2 at 30 and 50 DAT, respectively). This black/ silver plastic mulch is most effective than any other treatments in suppressing weed growth. The growth and development of tomato plant were increased remarkably by all the mulches over control and among the mulches; black/silver plastic significantly enhanced all the growth parameters. The highest plant height (138.8 cm at 70 DAT), stem base diameter (1.34 cm), number of primary braches per plant (4.8), number of leaves per plant (80.8) were observed under black/silver plastic mulch. Again, number of marketable fruits and total fruits/ plant (17.4 and 22.6, respectively), average fruit weight (65.2 g) and yield (48.38 t/ha) were also recorded significantly highest with black/silver plastic mulch followed by jute mulch. With the use of black/silver plastic mulch about 48% yield increment over control was observed.

Ensuing economic gains from vegetable Indian bean (*Lablab purpureus*) through effective weed management

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At present, more emphasis is given over the income of the farmers using different terminologies like doubling farmer's income, which requires either decrease of cost of production or increase in net income. Major cost of production in farming is under laborious operations like weeding and harvesting. A field experiment was conducted at Navsari during 2016-17 to find out cost effective weed management practices for vegetable Indian bean (*Lablab purpureus* L.) under south Gujarat condition. The tested weed management treatments comprised of total eight treatments *viz*. unweeded control, weed free (hand weeding at 20, 40 and 60 DAS), pendimethalin (EC) 1.0 kg/ha as pre-emergence (PE), pendimethalin (CS) 0.5 kg/ha as PE, pendimethalin (EC) 1.0 kg/ha as PE + HW at 40 DAS, pendimethalin (CS) 0.5 kg/ha as PE + HW at 40 DAS, imazethapyr 75 g/ha at 20 DAS, imazethapyr 75 g/ha at 20 DAS + HW at 40 DAS employed in a randomized block design with three replications. Results revealed that higher pod yield of vegetable Indian bean was obtained due to three hand weedings at 20 days interval up to 60 DAS under weed free treatment fetching highest gross monetary return of Rs. 60905/ha, but due to its higher cost of cultivation (` 36098/ha), the net returns from this treatment were lesser than pendimethalin (EC) 1 kg/ha as PE + HW at 40 DAS, pendimethalin (CS) 0.5 kg/ha as PE + HW at 40 DAS and imazethapyr 75 g/ha at 20 DAS + HW at 40 DAS. This was due to the cost incurred due to inclusion of labours as the main input of the treatment. Maximum net returns of ` 26343/ha were incurred due to the application of pendimethalin (EC) 1 kg/ha as PE + HW at 40 DAS followed by ` 25930/ha from pendimethalin (CS) 0.5 kg/ha as PE + HW at 40 DAS and ` 25232/ha from imazethapyr 75 g/ha at 20 DAS + HW at 40 DAS and resulted into economical weed management treatments for *Rabi* Indian bean. This was due to the use of chemicals and lesser labour requirement in these treatments. The lowest net monetary returns (` 17489/ha) was achieved under unweeded control. Whereas, the highest B:C ratio (1.87) was obtained from the treatment of imazethapyr 75 g/ha at 20 DAS + HW at 40 DAS to *Rabi* Indian bean which was closely followed by pendimethalin (EC) 1.0 kg/ha as PE + HW at 40 DAS, pendimethalin (CS) 0.5 kg/ha as PE + HW at 40 DAS, pendimethalin (EC) 1.0 kg/ha as PE and imazethapyr 75 g/ha at 20 DAS + HW at 40 DAS. The treatments with higher B:C may be recommended to the farmers with lesser capital for investing in the crop production.

Theme 3

Weed threat to biodiversity in forest, wasteland and aquatic ecosystem and socio-economic implications

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Effect of sowing method and weed management on weed parameters in pearl millet varieties

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Pearl millet [*Pennisetum glaucum* (L.) R. Br.] commonly known in India as *Bajra*. Pearlmillet (*Pennisetum glaucum* L.) is an important drought tolerant millet crop. Water logging during heavy rains and water stress during dry spells are the important factors for low productivity of pearl millet in Northern Madhya Pradesh. Present investigation was conducted during *Kharif* 2016 and *Kharif* 2017 at Instructional farm of RVSKVV, Krishi Vigyan Kendra Datia (M.P). Total 04 number of sowing method Broad casting, Line sowing, Ridge and furrow and Transplanting, with two varieties (V1- 86M86 (hybrid) and JBV-2 (composite)) and three weed management practices Hand hoeing at 20-25 DAS, Pre emergence application of atrazine at 40 gm/ha and Post-emergence application of 2, 4-D at 0.5 kg/ha) were tested during the experiment. The experiment was laid out in spilt plot design. The periodical observations were recorded on weed parameters *viz.* population/m^2, dry weight (g/m^2), weed control efficiency (%) and crop parameters *viz.* growth attributes, physiological attributes, yield attributes, computed parameters, quality parameters & economics as per prescribed procedures. The weed flora was observed in the experimental field included *Cyperus rotundus*, *Echinochloa* spp. and *Acrecne racemosa* under narrow-leaf; while *Digera arvensis*, *Celosia argentea* and *Phyllanthus niruri*, under broad-leaf during both the years of study. The population/ m^2 of *Cyperus rotundus*, *Echinochloa* spp. and *Acrecne racemosa*, *Digera arvensis*, *Celosia argentea*, *Phyllanthus niruri* and total weeds were controlled significantly under transplanting (15-20 days seedlings) followed by ridge and furrow sowing in comparison to rest of the treatments. The effective dry weight (g/m^2) of total weeds and weed control efficiency was recorded under transplanting (15-20 days seedlings); while losable value was notices under broadcasting. The significantly lowest population/ m^2 of *Cyperus rotundus*, *Echinochloa* spp. and *Acrecn eracemosa*, *Digera arvensis*, *Celosia argentea*, *Phyllanthus niruri* and total weeds was registered under 86M86 in comparison to JBV-2. The dry weight (g/m^2) of total weeds and weed control efficiency was found significantly effective under 86M86 in comparable to JBV-2. The effective control of all narrow-leaf and broad-leaf weeds was observed under one hand hoeing at 20-25 DAS/DAT followed by atrazine treated plot; while significantly higher count/m^2 with dry weight (g/m^2) were registered under 2, 4-D treated plot. One hand hoeing at 20-25 DAS/DAT plot noticed effective control of total weed flora; hence it recorded significantly higher weed control efficiency (%); while lower value was registered under 2, 4-D treated plot. The effective control of *Echinochloa* spp., *Acrecne racemosa* and total weeds was noticed under one hand hoeing at 20-25 DAS/DAT with interaction of transplanting (15-20 days seedlings). The significantly higher number/m^2 of weeds was higher in interaction of broadcasting with 2, 4-D treated plot over rest of the interactions.

The findings of studies clearly visualized that the transplanting (15-20 days seedlings) sowing method, 86M86 variety and one hand hoeing at 20-25 DAS/DAT as well as their interaction recorded significantly superior values of all weed parameters in comparison to others; which is suitable for gird agro-climatic conditions of Madhya Pradesh. After that in labour scarcity areas and economical basis; ridge and furrow sowing, 86M86 variety and one hand hoeing at 20-25 DAS/DAT as well as their interaction recorded significantly profitable values of all weed parameters in comparison to others; which is also suitable for gird agro-climatic conditions of Madhya Pradesh.

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A new disease of *Cyperus rotundus* caused by *Phytophthora cyperi-rotanduti* in Madhya Pradesh

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Cyperus rotundus has been considered as one of the world's obnoxious weed. It has been reported in many countries where it grows as a weed infesting almost all crops worldwide. It grows in all types of soils and can also survive humid and high temperatures conditions. It can be found in a wide range of habitats including river and stream shores, cultivated land, waste areas, roadsides, pastures, riverbanks, irrigation channels and natural areas. In India, *C. rotundus* is commonly known as Nagarmotha and it belongs to the family Cyperacea. The major chemical components of this sedge are cyprotene, cyperene, rotundene, cyperol, isocyperol, cyperotundone, aselinene, valencene including some flavonoids, essential oils, terpenoids *etc.* Pervious research studies have also shown that it possesses various pharmacological activities such as diuretic, analgesic, anthelminthic, anti-inflammatory, anti-dysenteric, antirheumatic, emmenagogue activities. It is used from ancient time as numerous therapeutic actions traditionally. Modern research revealed that the nagarmotha can be used as drug/medicine to cure many diseases in human. Each and every coin has two sides, apart from much medicinal importance *C. rotundus* behaves like a weed in the agriculture field. *C. rotundus* produces underground tubers from which they can regenerate and it is very difficult to control once established in crop surrounding. It is considered a nuisance for farmers because of its rapid growth and herbicide tolerance nature. *C. rotundus* was reported worldwide distribution in tropical and temperate regions. It has also been called "the world's worst weed". In the uplands, it is described as an important agricultural weed. Its presence in a field significantly reduces crop yield, both because it is a strong competitor for ground resources, macro/micro nutrients, water, space, sunlight *etc. C. rotundus* shows resistance to most herbicides. Most herbicides may kill the plant's leaves, but most have no effect on the root system and the tubers. During survey leaf spot disease in nutsedge was observed in rainy season. On the microscopic examination of infected part of sedge a fungus was found associated with them. In the present investigation, small yellowish brown lesions develop on leaves which gradually enlarge and cause leaf blight. These lesions eventually turn reddish brown. A white cottony growth appears on the leaves. Microscopic observation revealed abundant lemon shaped sporangia, it was semipapillate (apex); caduceus, elipsoid, pedicel 3-4 µm. In length, sporangia ellipsoid, ovoid or obpyriform, 32-50 x 19-30 µm. Chlamydospores not observed. The fungus readily forms oospores on leaves 25-31 µm in diameter, plerotic with paragynous antheridia. On the basis of microscopic observation of the pathogen it is identified as *Phytophthora cyperi-rotanduti*. Sporangia causes the same they of infection in healthy sedge plants. The pathogen was reported first time in the Madhya Pradesh on *C. rotundus*. It is can be used as mycohericide to manage this notorious weed.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Survival and growth of alligator weed from stolen node, internode length and burial depth in aquatic and terrestrial situations

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Alternanthera philoxeroides (Mart.) Griseb., or alligator weed, is a perennial, stoloniferous herb in the Amaranthaceae. Native to the region of the Parana River in South America, *A. philoxeroides* has been introduced to and become highly invasive in many other regions, including southern China. In India, *A. philoxeroides* does not produces viable seeds and instead reproduces asexually via stolons connected to established plants or through the establishment of dispersed fragments as small as a single ramet, *i.e.*, a stolon node capable of bearing roots and two opposite leaves. Dispersal of clonal fragments has resulted in a rapid expansion of the geographical range of *A. philoxeroides* in other countries from its native range. In China and in India, the species has become an important ecological and agricultural problem in both terrestrial and aquatic habitats.

The survival and success of any species depends on its ability to reproduce fast even in an adverse conditions. A plant may become fragmented on getting various types of disturbances both in aquatic and terrestrial situations. These fragments of different sizes with or without internode length may get submerged or float in the aquatic situation an may get buried at different depth under soils. This paper deeper burial in soils. We address (1) whether burial in soils decreases survival and growth of small clonal fragments, and (2) whether increasing internode length increases survival and growth of small fragments under burial. We conducted an experiment with the stoloniferous, invasive herb *Alternanthera philoxeroides,* in which single node fragments with stolon internode of 0, 2, 4 and 8 cm were buried in soils at 0. 2, 4 and 8 cm depth, respectively. The maximum germination was observed from the nodes placed on the surface of wet soil and least germination from the nodes buried at 30 cm depth. Germination of more than one emergent was recorded from single node in many cases. The germination from nodes decreased corresponding to the increase in depth. Likewise, growth of the emergent was maximum in case of surface and least in the 30 cm depth. The growth of emergent increased corresponding to the increase in days after germination.

Moisture greatly influence the germination and growth of alligator weed. In moist condition maximum germination and growth of new shoots was observed in the treatment where nodes were placed on the surface. There was 2.5 fold more germination from the nodes placed at the surface which decreased significantly buried below 2 cm depth, however, the number of emergent shoots increased about 5 and 7 times in 120 and 240 days, respectively while at 5, 10, 15 cm depth germination of emergent shoot was 5, 3 and 2 fold from the initial 50 nodes after 120 days of their burial in soil.

Increasing burial depth significantly reduced survival of the *A. philoxeroides* plants and increased root to shoot ratio and total stolon length, but did not change growth measures. Increasing internode length significantly increased survival and growth measures, but there was no interaction effect with burial depth on any traits measured. These results indicate that reserves stored in stolon internodes can contribute to the fitness of the *A. philoxeroides* plants subject to disturbance. Although burial reduced the regeneration capacity of the *A. philoxeroides* plants, the species may maintain the fitness by changing biomass allocation and stolon length once it survived the burial. Such responses may play an important role for *A. philoxeroides* in establishment and invasiveness in frequently disturbed habitats.

Identification of nitrate/nitrite rich weeds and analysis of water bodies in and around the farm land of Shivamogga, Karnataka

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Nitrate/nitrite produces both acute and chronic toxicities in ruminants. Repeated application of nitratic fertilizers are known to cause accumulation of nitrate/nitrite in certain weeds or fodder crops in the farmland, apart from contamination of water bodies in and around it. Hence the present study was conducted with the objective of ascertaining the level of nitrate/nitrite in common farm weeds and water bodies (drinking water source) in and around the farm land. The investigation was carried out in various locations of *Gomala* (grazable land) of Shivamogga, Karnataka State during the month of early monsoon. The representative farm weeds were subjected to standard diphenylamine test for presence or absence of nitrate. The water samples obtained were subjected to semi quantification analysis of nitrate/nitrite using Nitrate TestKit® and Nitrite TestKit® (HiMedia Laboratories, Mumbai).

In the present study, most of the underground water samples like borewell water, were found to contain 100 ppm of nitrate and appears to be unsafe as drinking water source, whereas water samples of other sources like channel water, pond, tank, lake and river water showed presence of nitrate at safe limits. The crop plants *viz.*, *Sorghum vulgare, Zea mays* and *Vigna unguiculata* grown in water logged conditions showed presence of nitrate. Weeds like *Achyranthes aspera* (L.), *Aeschynomene indica* (L), *Ageratum conyzoides* (L), *Alternanthera sessilis* (L), *Celosia argentea* (L), *Chromolaena odorata, Commelina benghalensis, Synedrella nodiflora, Crotalaria verrucosa* are highly positive for nitrate/nitrite.

Hence, these plants could serve as indicators of nitrate rich soil in farm land. Thus, regular screening of weeds in and around farmland is essential to execute necessary farm land management practices to overcome potential health hazards to livestock.

Theme 4

Herbicide resistance in weeds and herbicide tolerant crops

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Herbicide resistance in weeds

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Herbicides are used extensively for weed control in crop production throughout the world. One consequence of the extensive use of herbicides has been the appearance of herbicide resistance in weed species. Herbicide resistance is known in all areas where herbicides are used intensively. Herbicide-resistant weeds are a constraint to weed management in many cropping regions around the world. Herbicide resistance is the genetic capacity of a weed population to survive a herbicide treatment that, under normal use conditions, would effectively control that weed population. Herbicide resistance is an example of evolution happening at an accelerated pace and an illustration of the "survival of the fittest" principle. A herbicide may kill all the weeds in a population of a particular weed species except for a few individuals with the genetic capacity to survive the herbicide. Herbicide resistant weeds are normally very rare in a weed population. Applying the same herbicide in the same field year after year will select for resistant plants. The resistant weeds set seed and may eventually dominate the population. This population is then not effectively controlled by the selecting herbicide. Of the numerous populations of weeds with resistance to herbicides, it appears that most have resistance due to an alteration to the target enzyme. The International Survey of Herbicide-Resistant Weeds reports 388 unique cases of herbicide-resistant weeds globally, with 210 species. Weeds have evolved resistance to 21 of the 25 known herbicide sites of action and to 152 different herbicides. The acetolactate synthase inhibitors (126 resistant species) are most prone to resistance, followed by the triazines (69 species), and the acetyl-coA carboxylase inhibitors (42 species) and these numbers are increasing fast with the accelerated use of the same herbicides, year after year, without practicing herbicide rotations, integrated weed management and like options which discourage and postpone the problem of herbicide resistance in weeds. In India *Phalaris minor* in wheat and *Echinocloa* spp. in rice developed herbicide resistance. Herbicide resistance is classified as cross resistance and multiple resistance. The cross resistance is said to have occurred when a weed biotype is found resistant to more than one herbicide species, all of which possessed the same phytotoxic action mechanism. Multiple herbicide resistance occurs when a weed species is no longer controlled by two or more herbicides with different sites of action applied at labeled rates. (Earlier these herbicides would have provided effective control of this species at the same application rates.) In other words, the weed species with multiple-resistance has acquired resistance against herbicides belonging to different chemistries. This is due to over reliance or continuous use of two or more selected herbicides over time. Multiple-resistance has been reported in several weed species. The discovery of new herbicide sites of action and new herbicide-resistant crop traits will play a major role in weed control in the future however growers must make the transition to integrated weed management that utilizes all economically available weed control techniques.

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Tolerance of wheat to topramezone plus clodinafop-propargyl: A new herbicide mixture for weed control in wheat

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Wheat is the main crop of winter season in NW India. Among the various factors, which adversely affect the yield of wheat crop, weed infestation is the most harmful one but less noticeable. It is infested with number of grass and broad-leaf weed species. The major weed species of wheat field include *Phalaris minor*, *Avena ludoviciana*, *Rumex dentatus*, *Chenopodium album*, *Coronopus didymus*, *Convolvulus arvensis etc. Phalaris minor* is the most problematic weed in rice-wheat system which has been the dominant cropping system in NW India. Reports of weeds that are resistant to herbicides are now common in almost every country and in almost all crops where herbicides are routinely used for weed control. Repeated use of same group of herbicide led to development of resistance to herbicides of three modes of action commonly used for its control. There is an urgent need to identify new herbicide having modes of action different from the existing herbicides available for weed control in wheat. However, before taking any new herbicide to the farmers the tolerance of the crop to new herbicide is very important. In this context, the studies on tolerance of wheat of the new herbicide topramezone 48 g/L + clodinafop-propargyl 96 g/L was conducted at Regional Research Station of PAU at Bathinda during *Rabi* 2016-17. The study consisted of nine treatments, *viz.* topramezone plus clodinafop at 72, 90, 108, 144 and 216 g/ha and; clodinafop 60 g/ha, metsulfuron-methyl 4/ha, weed free check (hand weddings) and control (weedy) in RBD in three replications. Herbicidal treatments were applied as post-emergence at 2-3 leaf stage of weeds. Before the application of herbicide, non-significant differences in weed population were observed among the different treatments. Application of topramezone plus clodinafop at 108, 144 and 216 g/ha reduced population of both grasses and broad-leaf weeds significantly as compared to control plot. Topramezone plus clodinafop application at 108, 144 and 216 g/ha were equally effective against grasses and broad-leaf weeds like clodinafop and metsulfuron, respectively. All herbicide treatments (five doses of topramezone plus clodinafop, clodinafop and metsulfuron-methyl) gave similar wheat grain yield to weed free check and the herbicide was safe to wheat crop at the dosage tested and no herbicidal photo-toxicity was recorded. The new herbicide mixture was found to be safe for use in wheat crop. However, studies on tolerance of local wheat varieties popular in an area to the new herbicide need to be undertaken before making its recommendation at the local level.

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Imazethapyr resistant *Echinochloa colona* biotypes in Madhya Pradesh

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Echinochloa colona (jungle rice), is a hexaploid (2n 5 6x 5 54) (Gould *et al.* 1972; Yabuno 1966) and native to India (Alarcon-Reverte *et al.* 2013), and an important weed of soybean (*Glycine max*). Soybean is growing mainly in central India *i.e.* Madhya Pradesh. It suffers severely due to weed infestation causing a reduction in the yield of soybean from 58-85%, depending upon the types and intensity of weeds (Kewat *et al.* 2000). Imazethapyr an ALS inhibitor herbicide has been commercialized and continuously used since last 10 years for controlling the weeds in soybean. Herbicide resistance occurs when a weed is no longer controlled by an herbicide at rates that previously were effective. There are currently 495 unique cases of herbicide resistant weeds globally, with 255 species (148 dicots and 107 monocots). Weeds have evolved resistance to 23 of the 26 known herbicide sites of action and to 163 different herbicides. Herbicide resistant weeds have been reported in 92 crops in 70 countries. A total of five cases of herbicide resistance has been reported from India in two weed species (*Phalaris minor* and *Rumex dentatus*). *Phalaris minor* has evolved multiple herbicide resistance (MHR) across three modes of action: photoynthssis at photosystem II site A, acetyl-coA-carboxylase (ACCase) and acetolactate synthase (ALS) inhibition. A recent case of herbicide resistance in India has been reported in *Rumex dentatus* against ALS (metsulfuron) (Chhokar 2014).

To evaluate the selection pressure of Imazethapyr for *Echinochloa colona* in soybean, we have surveyed of 20 soybean growing districts of Madhya Pradesh, *viz.* Indore, Ujjain, Dhar, Ratlam, Mandsaur, Agar, Rajgarh, Shajapur, Bhopal, Damoh, Sagar, Tikamgarh, Chhattarpur, Ashok Nagar, Guna, Dewas, Harda, Sehore, Hoshangabad and Raisen during *Kharif* 2016. Simple random sampling was used to collect the weed seeds under study. Only physiologically mature seeds were collected. Seeds were collected from 5-7 locations in each field and bulked together to make single sample. The GPS coordinates were noted down at every location throughout the survey. A total of 93 seed samples of *E. colona* were collected. We have collected the samples by interacting with the farmers, where imazethapyr efficacy was less. During *Kharif* 2017, the collected seeds of *E. colona* (93 biotypes) were sown in plastic pots of 20 cm diameter and 22 cm height. The pots were filled with field soil and arranged in completely randomized block design and replicated thrice. The tested herbicide (imazethapyr) was applied at 100, 200 and 400 g/ha at 4-5 leaf stage of *E. colona* biotypes. For confirmation of the resistance of biotypes, the harvested seeds from previous season (*Kharif* 2017) were again tested in *Kharif* 2018. It was found that, out of 20 district *E. colona* biotypes of 15 districts was showing resistance against imazethapyr at recommended dose even few of them showing resistance at higher (upto 4X) than the recommended dose (X) of imazethapyr. The degree of resistance varied with different districts of MP.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Chlorophyll fluorescence of isoproturon resistant *Phalaris minor* treated with different herbicides

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Chlorophyll fluorescence measurement is a non-invasive method for imaging photosynthetic fluxes because chlorophyll fluorescence depends directly on photosynthetic activity. It is a defense mechanism or excess energy dissipation that is highly linked to the photosynthetic process. Undoubtedly the development of isoproturon-resistant *Phalaris minor* is an epidemic in wheat production mainly. The resistance case was first reported in 1995 and it was the most serious incident of herbicide resistance in the world ever, resulting in entire crop failure from serious weed infestations. The pot experiment was conducted during the winter season of 2016-17 at the department of Plant Physiology, Govind Ballabh Pant University of Agriculture & Technology, Pantnagar. The present study was undertaken to observe chlorophyll fluorescence variable yield of isoproturon resistant *Phalaris minor* under different herbicides. In this experiment, isoproturon resistant *Phalaris minor* were sown in pots with three replications and eleven treatments. It includes two pre-emergence treatments (pendimethalin at 750 g/ha and metribuzin at 210 g/ha), eight post-emergence treatments; clodinafop-propargyl 60, 90, 120 g/ha, pinoxaden at 50 g/ha, sulfosulfuron 25, 62.5 g/ha, metribuzin at 210 g/ha, halauxifen methyl + pyroxsulam at 60 g/ha and unsprayed control. Pre- and post-emergence herbicides were applied at 1 and 40 days after sowing respectively. Chlorophyll fluorescence (Fv/Fm ratio) can be variably correlated with the photochemical yield of PS-II. It has been used widely to detect the effect of herbicides of different modes of action in crops and weeds. It has been reported that herbicide application reduces Fv/Fm due to the slowing of quenching processes ad damage of PS-II reaction centre. Difference in Fv/Fm was reported in ALS inhibiting herbicide treated plants of *Phalaris minor.* The Fv/Fm which reflects potential quantum yield of PS-II indicates the physiological state of the photosynthetic apparatus in intact plant leaves. Reductions in fluorescence were observed in plants treated with herbicides that inhibit amino acid synthesis. In case plant suffers from any diseases or abiotic stress it may reflect lower level of Fv/Fm ratio. Application of pre-emergence herbicides tended to reduce Fv/Fm and give insights into the ability of a plant to tolerate chemical stress. The pre-emergence herbicide treatments effectively control the germination of the weed while the population of isoproturon resistant *Phalaris minor* was rapidly declined after application of post-emergence herbicides. The double doses of applied herbicides were found more effective to control the weed. Among the post emergence herbicide treatments, halauxifen methyl + pyroxsulam was found ineffective to control the weed compared to other treatments.

ALS/AHAS (Group B/2) inhibitors resistance in *Rumex dentatus* L. and *Chenopodium album* L. halting future wheat productivity of Haryana and Punjab

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Wheat is cultivated over an area of approximately 30.23 million hectare in India, which produces 93.50 million tonnes with a productivity of 30.93 quintals per hectare. Weed infestation is one of the major biological constraints in wheat production in India and chemical weed control methods are primarily used by growers. Presently, multiple resistance in *P. minor* is causing huge grain yield reductions in wheat in both Punjab and Haryana (Singh 2007; Chhokar and Sharma 2008). Performing at same tropic level, *Rumex dentatus* L. possess higher aggressivity and competitiveness as compared to wheat for resources, subsequently reducing the crop yield besides interference with combine harvesting. *Rumex dentatus* became a serious problem of irrigated wheat particularly of rice-wheat system and build up is more under zero-till conditions (Sharma *et al*. 2004). This will be emerged as future weed under no till due to hike in area under conservation agriculture that favours this weed ecologically. *Rumex dentatus* was found resistant to metsulfuron and also exhibited cross resistance to florasulam, pyroxsulam, iodosulfuron and triasulfuron, while *Chenopodium album* was found resistant to metsulfuron (Chhokar *et al*. 2017). Keeping in view the above aspects and for further analysis of gravity of resistant in *Rumex dentatus* and *Chenopodium album,* a survey was conducted in major rice-wheat cultivated districts of Haryana and Punjab and seeds were collected from farmer's fields having uncontrolled history during 2016-17.

In Haryana, total 56 populations of *Rumex dentatus* were collected from Kaithal (8), Kurukshetra (11), Karnal (14), Ambala (8), Panchkula (2), Panipat (3), Yamunanagar (5) and Jind (5). These populations were grown in pots at Research Farm, PAU (Ludhiana) and were sprayed with metsulfuron 5 g/ha at 3-4 leaf stage with knap sack sprayer using 375 litres of spray volume. Out of total, 38 biotypes were found resistant to ALS inhibitor and resistance pattern was almost similar in every district of Haryana. The reasons for failure of chemical weed control at other locations might be poor spray technology or use of sub-lethal dose of herbicide. *Chenopodim album* populations were collected from Kaithal (8), Kurukshetra (6), Karnal (12), Ambala (3), Panchkula (1) and Jind (6) with total of 36. Out of these, 9 biotypes were found resistant and were mostly confined to Kaithal district (6 biotypes). In Punjab, from farmers' fields in Jalandhar, Ludhiana, Barnala and Sangrur districts, 7 populations of *Rumex dentatus* and 6 populations of *Chenopodium* were collected. Only one biotype of *Rumex dentatus* collected from Barnala district showed resistance to metsulfuron. The intensive and periodical scouting is required to broaden the knowledge about their geological distribution, resistance mechanism, biological fitness, and dynamics of growth response in relation to fickle climate to rectify resistance gravity *vis a vis* development of strategic means for their management.

Control of multiple herbicide resistant *Phalaris minor* with ready mix of pendimethalin and metribuzin in wheat

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Phalaris minor Retz. is a common troublesome grass weed in wheat in Punjab. Many post-emergence herbicides are commonly being used against this weed. Moreover, Punjab farmers continued to have preference of post-emergence over the pre-emergence herbicide. Currently, *P. minor* has evolved resistance to many of the commonly used POST herbicides across three modes of action-phenyl urea, ACCase and ALS inhibitors, indicating the need to shift from post to pre-emergence herbicides. Added to this, the seed bank of resistant *P. minor* has increased many folds over the years. Pendimethalin, as a single PRE herbicide has been recommended for its control in wheat since 1982-83 in Punjab. Now, this weed is posing a major threat to wheat productivity in this region. In this context, the study was conducted to evaluate the bio-efficacy of pendimethalin plus metribuzin against *P. minor* in wheat. The experiment was laid at PAU, Ludhiana during *Rabi* 2014-15 and 2015-16 with six treatments in Randomized Complete Block Design. The treatments were ready mix of pendimethalin 40% plus metribuzin 8% EC 960 g/ha, 1200 g/ha, pendimethalin 800 g/ha, metribuzin 160 g/ha, weed free and weedy check (control). Wheat variety *'HD 2967'* was sown on 04.11.2014 and 02.11.2015 by using 100 kg/ha seed. Recommended doses of fertilizers were applied to the crop. The herbicides were applied as pre-emergence with knapsack sprayer fitted with flood zet nozzle. The data on weed density of *P. minor* were recorded at harvest using 50 x 50 cm quadrat. The grain yield was recorded at harvest. The weed data was analysed statistically after square root transformation. *Phalaris minor* was the dominant grass weed in experimental field during both the years.Significantly less density of *P. minor* was recorded in pendimethalin plus metribuzin 960 and 1200 g/ha than standard herbicides pendimethalin and metribuzin. Among all the treatments, pendimethalin plus metribuzin 1200 g/ha recorded higher weed control efficiency than 960 g/ha and found superior to all other treatments with respect to weed control and hence attained higher grain yield. The efficacy of pendimethalin plus metribuzin was increased as the dose was increased from 960 to 1200 g/ha. Ready mix of pendimethalin plus metribuzin 1200 g/ha was significantly superior to pendimethalin, metribuzin and weedy check. Highest grain yield of 6.24 and 6.23 t/ha was recorded with pendimethalin plus metribuzin 1200 g/ha, respectively in 2014-15 and 2015-16, at par with hand weeding (6.29 and 6.19 t/ha) and significantly higher than pendimethalin plus metribuzin 960 g/ha (6.01 and 6.05 t/ha), respectively in 2014-15 and 2015-16. Remaining herbicidal treatments recorded the grain yield between 5.18 and 5.55 t/ha in both the years. Based on two year studies, it is concluded that pre-emergence application of ready mix of pendimethalin plus metribuzin 1200 g/ha provides effective management of herbicide resistant *P. minor* in wheat and recorded the highest wheat grain yield.

Productivity and profitability of onion through integrated weed management

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Onion (*Allium cepa* L.) belonging to family Alliacea is one of the most important and export oriented crop grown all over the world including India. It is a condiment crop and consumed as fresh salad and added as a spice while cooking dishes. It is a good source of minerals, vitamins, Polyphenol and a number of phytonutrients. India ranks first in area and second in production with about 19.9% share after china in the world.

High weed is a limiting factor for lower production of Onion in the district due to poor management. Under traditional cultivation frequent irrigation and fertilizer were given during crop growth and development but the slow growth rate at initial stage of crop favors the congenial environment for the weed growth and weed compete with crop plants for moisture, nutrients, light and space which resulted 40-80% yield loss. Hand weeding is more effective to enhance the yield of Onion but very laborious, expensive and time consuming.

Front Line Demonstration was laid down by Krishi Vigyan Kendra, Sagar on integrated weed management on onion during *Rabi* season of 2014-15 and 2015-16 at 20 farmers field in three villages of Sagar district of Bundelkhand region with medium fertility status soils in Sagar district of Madhya Pradesh for popularization of integrated weed management in onion. To find out the constraints in onion production, Participatory Rural Appraisal (PRA) technique was used. Preferential ranking technique was utilized to identify the constraints faced by the respondent farmers in onion production. The treatments for weed management were taken as farmers practice – two to three hand weeding and recommended technology - spray of oxyflourphen 23.5 EC at 250 ml/ha or quizalofop-ethyle 5 EC at 750 ml/ha at 20 DAP and one hand weeding at 40-45 DAP. The data on weed infestation was taken from demonstration plot as well as farmers practice. The cost of cultivation, gross monetary return and benefit cost (B: C) ratio were calculated based on current market price. In addition to this, data on farmer practices were also collected from the equal area.

The average minimum density of weeds was 6.8 per cent in oxyflourphen 23.5 EC at 250 ml/ha or quizalofop-ethyle 5 EC at 750 ml/ha sprayed plots in comparision to farmer's practices where weed density were 9.8 per cent. The integrated management of weeds increased yield of onion by 24.3 (17.6 to 21.7 t/ha) against farmer's practices. The economic viability of integrated weed management over traditional farmer's practices was calculated depending on prevailing prices of inputs and output costs. It was found that average cost of production of onion under improved production technologies was 62,250 per ha in both the years over farmers practice which was 57,500 per ha. In the IWM technology additional net return of ` 29,500 per hectare were gained by the farmers without any increase in cost of cultivation. The technology also gave higher benefit cost ratio 3.37 as compared to 2.64 under farmers practice. The results from the current study clearly brought out the potential of integrated weed management in onion cultivation in Sagar district of Madhya Pradesh.

Theme 5

Non-chemical weed management including biological control

Nutrient management in organic rice and its effect on beneficial soil micro organisms

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A field study was conducted during *Kharif*, 2017 at Instructional cum Research farm, IGKV, Raipur, in an Inceptisol with rainy season rice to evaluate the effect of different combinations of organic manures along with biofertilizers on – physico-chemical, microbial, biochemical properties of soil and crop yield. Different chemical and non–chemical weed management techniques were also evaluated to find out their suitability. Three different types of organic manures – FYM (Farm Yard Manure), Poultry manure, Vermicompost were mixed in different combinations. Nitrogenous and phosphatic biofertilizeres- *Azospirillum* and PSB (Phosphorus Solubilizing Bacteria) were also applied through seed inoculation uniformly to all the organic manure treatments. The combinations of organic manures were done in such a way so that the crop N demand could be fulfilled. Three treatments - FYM (50% N) + Vermicompost (50% N) + *Azospirillum* + PSB, FYM (50% N) + Poultry Manure (50%N) + *Azospirillum* + PSB and FYM (50% N) + Vermicompost (25% N) + Poultry Manure (25% N) + *Azospirillum* + PSB put in main plots. Different weed control practices have also been evaluated to find out their suitability for organic farming of rice, compared with weedy check. The weed control practices are- Hand weeding, motorized weeding (single row type), recommended herbicides application (oxadiargyl 80 g/ha as pre-emergence and *fb* bispyribac 25 g/ha as post-emergence) which were put in sub plots, motorized weeding (double row type), green manure (30 DAS) and paddy weeder (manual) which were put in sub plots. These treatments were compared with weedy check to evaluate their efficiency. The results of the investigation revealed that the 50% nitrogen management through FYM, 50% by poultry manures and application of biofertilizers *Azospirillum* and PSB was found most effective to improve the physico-chemical, biochemical microbial properties of soil and crop yield. Soil organic carbon was also found at maximum level due to above combination of organic manures. Maximum microbial activities like – Dehydrogenase activity, Basal soil respiration, Microbial Population – *Azospirillum* and PSB (Phousphorus Solubilizing Bacteria) were found under this nutrient management system. Higher soil respiration, Dehydrogenase Activity and Microbial Population (*Azospirillum and* PSB) were also recorded in this system. Among different weed control systems application of recommended herbicides found most effective to increase the rice yield significantly. However, among non-chemical weed management methods hand weeding was found superior over motorized weeding (double row type) but at par with single row type mechanism to improve the crop yield. In microbial and biochemical studies motorized weeding (double row type) performed best among all studied weed management practices, which found at par with hand weeding. In many cases hand weeding performed best among all, particularly at 90 DAS. Application of pre-emergence and post-emergence herbicide reduced the microbial and biochemical activities in soil from its application (6 and 30 days after sowing, respectively) to 30 days after sowing of the crop there after due to its degradation the microbial and biochemical activities in the soil system improved and reached to a maximum at 90 DAS. Control (weedy check) condition facilitated more microbial and biochemical activities in rhizosphere soil which might be due to higher root density per unit area caused greater rhizosphere effect.

Weed management options under organic mode of rice-wheat cropping system

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Weeds are often recognized as the most serious threat to organic crop production and fear of ineffective weed control is often perceived by farmers as one of the major obstacles to conversion from conventional to organic farming (Beveridge and Naylor 1999). Weed management is often approached from a reductionist perspective, *e.g.* focusing only on the comparison between types and adjustments of implements for mechanical weed control in a given crop. This 'conventional' approach neglects the systemic ('holistic') nature of organic agriculture, which has long been recognized as a pillar for the design of real, effective organic crop production systems (Andrews *et al*. 1990; Lockeretz 2000).

Hence, a research experiment was conducted during 2016-17 and 2017-18 at G.B.P.U.A and T., Pantnagar to study the performance of organic weed management practices against the complex weed flora in rice-wheat cropping system. The experiment consisted of eight treatments *viz.* TPR - Summer ploughing + stale bed + 1 MW (20DAT) + 1 HW (40 DAT), TPR - Stale bed + 1 MW (20 DAT) + 1 HW (40 DAT), TPR -Soil solarization + 1 HW (40 DAT), T4: FIRB DSR –Stale seedbed + soybean on bed) + 1 Hoeing at 20 DAS + 1 HW at 40 DAS, DSR + *Sesbania* + MW (25 DAS) + HW (40 DAS), DSR- Soil solarization + one HW (25 DAS), TPR + Pre-em *fb* Po-em herbicide and DSR + Pre-emergence *fb* post-emergence and replicated thrice.

Under organic mode of cultivation of rice during 2016-17, lowest dry biomass of *E. colona* was recorded with soil solarized transplanted rice supplemented with one hand weeding (40 DAT) which was comparable to conventional direct seeded rice either seeding done on FIRB under stale bed along with one mechanical and hand weeding as well as transplanted rice where summer ploughing followed by stale seed bed along with supplementation of one mechanical and hand weeding (20 and 40 DAT), respectively. *E. colona* and *F. miliaceae* were not observed under direct seeded rice on soil solarized beds followed by one hand weeding. However, *F. miliaceae* also got eliminated with transplanted rice on soil solarized bed followed by one hand weeding as well as in direct seeded rice.

Total density of all the grassy and non grassy weeds were recorded least with direct seeded rice incorporated with *sesbania* followed by one mechanical and hand weeding during 2017-18. Grain yield was not significantly influenced by the treatments during 2016-17. FIRB DSR as well as transplanted rice with summer ploughing + stale seed bed followed by one mechanical followed by one hand weeding recorded higher grain yield and superior to rest of the treatments in 2017-18.

Weed management in organic maize-garlic production system

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Agriculture in Himachal Pradesh is the main occupation employing 71% of the working population. It accounts for 21.1% of the total domestic product. The main problem in crop production is the occurrence of weeds which interfere with the crop and cause huge losses in yield. Weeds are further more serious to organic crop production and fear of ineffective weed control is often perceived by farmers as one of the major obstacles to conversion from conventional to organic farming. Since synthetic chemicals are not allowed, weed control is a great challenge under organic production systems. Potent methods of non-chemical weed control that could be used in organic systems involves both direct and indirect methods such as intercropping, stale seed bed, raised beds, crop rotations, mulches and cover crops.

Ten treatments *viz.* Hoeing *fb* earthing up in maize and hoeing twice in garlic (T_1); stale seed bed (SSB) *fb* hoeing and earthing up in maize and SSB *fb* hoeing + hand weeding in garlic (T_2); raised stale seed bed in *fb* hoeing *fb* earthing up in maize and RSSB *fb* hoeing + handweeding in garlic (T_3); mulch in both maize and garlic (T_4); SSB + mulch both in maize and garlic (T_5); RSSB + mulch both in maize and garlic (T_6); intercropping (soybean in maize and coriander/methi in garlic) (T_7); rotation of crops (maize/soybean in *Kharif* and garlic/pea in *Rabi*) *fb* hoeing *fb* earthing up in *Kharif* and hoeing and hand weeding in *Rabi* (T_8); intensive cropping *i.e.* mulch + manual weeding in *Kharif fb* autumn of coriander and mulch + manual weeding in *Rabi fb* green manure crop in summer (T_9) and chemical check (atrazine + pendimethalin in maize and pendimethalin in garlic + handweeding if required) (T_{10}) are being tested in RBD with three replications.

There was significant variation in the count of grassy weeds. Intercropping of soybean with maize (T_7) resulted in significantly lower count of grassy weeds. Sedges were found to be sensitive to intercropping competition and were completely eliminated under T_7. Treatments brought about significant variation in total weed count. Intercropping (T_7) resulted in significantly lower total weed count. The other treatments were more or less similar to chemical check (T_{10}). Intercropping treatment (T_7) resulted in higher cob weight significantly more than chemical check but it was comparable to other treatments. T_7 being at par with T_6 (raised stale seed bed + mulch) resulted in significantly higher maize green cob yield over rest of the treatments. T_7 (intercropping of soybean) increased maize green cob yield by 114.2% over the chemical check. There was also significant variation in bulb yield of garlic. Raised stale seed bed + mulch resulted in significantly higher bulb yield of garlic as compared to other weed control treatments. Bulb yield ranged from 1.27 to 3.36 t/ha under different treatments. All treatments were comparable in influencing green fodder yield of maize during the *Kharif* 2017. Due to higher bulb yield of garlic, garlic equivalent yield was highest under raised stale seed bed + mulch applied both in maize and garlic.

Non-chemical methods of weed management in wheat under organic production system

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Weed management is a key issue in organic farming system. Different cultural and mechanical practices can provide a sigh of relief for the growers with no chemical application in agriculture. Stale seed bed conditions by pre-sowing irrigation or rainfall induce sprouting of weeds and subsequent harrowing makes land free from weeds in initial stages of growth. Intercropping within the organic agricultural production has an important role in weed control. Intercropping use resources more effectively than a monoculture and thus decrease the amount available for weeds use. Keeping in view the negative effects of herbicides, and increasing demand of organic products, the present investigation was carried during *Rabi* 2015-16 at Model Organic Farm of Department of Organic Agriculture CSK HPKV, Palampur to study non-chemical methods of weed management in wheat under organic production system. The experiment was laid out in split plot design with three replications comprising of seed bed manipulations (standard and stale seed bed) in main plots and seven weed management practices (one manual hoeing, two manual hoeings, gram intercropping (no weeding), gram intercropping + one manual hoeing, natural farming (mulching), natural farming (gram intercropping + mulching) and weedy check) in sub plots. The soil of the experimental site was silty clay loam in texture, acidic in reaction, low in available nitrogen, high in available phosphorus and medium in available potassium. The major weed flora of the experimental plots consisted of *Phalaris minor* Retz., *Avena fatua* L., *Lolium temulentum* L. and *Poa annua* L. among grasses; *Anagallis arvensis* L. and *Vicia sativa* L. among broad-leaf weeds. *Phalaris minor, Avena fatua* and *Lolium temulentum* were the major weeds constituting 27.29, 23.18 and 19.51%, respectively, of total weed flora at 120 days after sowing. Stale seed bed resulted in lower total weed density and dry matter accumulation over standard seed bed. However, standard seed bed recorded 8.22% higher wheat equivalent yield and 12.46% higher net returns over stale seed bed. Gram intercropping + one manual hoeing being statistically at par with two manual hoeings recorded lower total weed density and dry matter accumulation, higher weed control efficiency (72.6%) and wheat grain equivalent yield (3955 kg/ha). Two manual hoeings recorded higher net returns (` 84,064/ha) but it remained statistically at par with gram intercropping + one manual hoeing (` 80,941/ha). Both natural farming (gram intercropping + mulching) and natural farming (mulching) treatments recorded significantly highest net returns per rupee invested of 3.32 and 3.10, respectively.

Biological control of *Parthenium hysterophorus*

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Parthenium hysterophorus L., commonly known as carrot weed or congress grass in India. It has been considered as one of the worst weeds responsible for causing health problems in men and animals besides loss to crop productivity and plant biodiversity. (Bhateria *et al.* 2015). The weed has infested about 35 million hectares of land in India since its first notice in 1955. Biological control is an environmentally sound and effective means of reducing or mitigating pests and pest effects through the use of natural enemies. Biological control of weeds includes the introduction of foreign pathogenic organisms, called the 'classical approach', and the 'augmentative' or 'bioherbicidal approach',

Biological control of weed is the intentional manipulation of natural enemies by man for controlling harmful weeds. Different plant species like *Xanthium strumarium, Cassia tora, Hyptis suavelones etc.*, were found to compete with *Parthenium* (Sarkate and Pawar 2005, Gaikwad 2006). In Madhya Pradesh, the use of marigold was also advocated to suppress the growth of *Parthenium* in the protected areas (Kauraw *et al.* 1997). Under classical biological control of *Parthenium* in India, three insect species were imported in 1983 from Mexico, out of which only host-specific leaf-feeding beetle *Zygogramma bicolorata* Pallister (Coleoptera: Chrysomelidae) was proved successful. Z. *bicolorata* has established in many parts of the country and has been found responsible to decrease the *Parthenium* densities in different parts of India. (Jayant 1987, Singh 1997).

Biological control indicate that *Parthenium* management through bioagents can not be as simple as in some other successful cases because of high regeneration capacity, large seed production ability, germination ability through out the year and extreme adaptability of *Parthenium* in wide range of ecosystem, Bhan *et al.* (1997). There is a need of some integrated management with biointensive approach: Augmentation of *Zygogramma bicolorata* can be achieved through mass multiplication throughout the year. The role of marigold for parthenium suppression can be achieved at one hand while aesthetic value on the other hand. Different type of parthenium competitive plants should be indentify at local region. There are many ways like mechanical, chemical, cultural and biological to control it, but it cannot be controlled by using a single approach. Integrated approach should be the better way to manage this noxious weed.

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Non-chemical approaches to manage *Parthenium hysterophorus*

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Parthenium hysterophorus is a weed of global significance which is easily to visible in any land of India with many more common names like Congress grass, Carrot grass, White top etc. It is an herbaceous, erect and annual plant belonging to family Asteracae (Compositae). The origin of *Parthenium* is considered to be from Mexico, America, Trinidad and Argentina. After noticeable occurrence of *Parthenium* in Pune (Maharastra) in 1955, it has spread like a wild fire throughout India. At present, it invaded 35 million hectare agricultural land in India. A single plant can produce about 5000-25000 seeds which are very small in size and light in weight this makes it most common weed of both crop and non-crop area. In general, *Parthenium* is poisonous, problematic, allergic and aggressive weed posing a serious threat to human being and livestock and also reduces the asthetic value of parks, gardens and residential colonies. It considered as one of the major source of dermatitis, asthma, nasal-dermal and nasal-bronchial types of diseases in Australia and India. The strong potential of *Parthenium* plant to produce 1,54,000 seeds/m^2 coupled with easy transportation with water and wind, capacity to regrow from the cut of broken parts. It has an allelopathic effect with absence of natural enemies like insect and diseases are most important factors responsible for its rapid spread in India. *Parthenium,* due to its aggressive nature rapidly spread in India and many other countries, many efforts are being made to control or to manage this noxious and problematic weed. It can be controlled by chemical, mechanical, cultural, and the most advanced biological management methods. Although chemical control is an effective method to control it where its natural enemies are absent but the hazardous and harmful short as well as long lasting effects of these chemicals on soil, ecology, environment, and the health of human being and livestock can't be avoided. So, in this situation the most appropriate way to control any weed is nonchemical control in a sustainable manner. Through mechanical (physical) control methods like manual uprooting of *Parthenium* before flowering and seed setting is the most effective method, burning is also another method to control. The most modern and classical approach to control *Parthenium* is biological control. Biological control is an ecofriendly and effective way of reducing pest and pest effects through the use of natural enemies. *Parthenium* is generally controlled by various biological agents like microbial pathogens and insects. The leaf eating caterpillar *(Zygogramma bicolorata)* and the stem galling moth *(Epiblema sternuana*), both exported from Mexico have shown good potential to control this weed in environmentally sound way. These agents skeletonized plant leaves within 4-8 weeks. This method is slow but is the most effective and appropriate strategy. In this present scenario of environment pollution it provides better way for achieving sustainability of our environment.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Utilization of Congress grass (*Parthenium hysterophorus* L.) for improvement of soil fertility and crop productivity under different crop sequences in West Bengal

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Congress grass (*Parthenium hysterophorus* L.) is an invasive alien weed of international importance. The weed is posing a serious threat to agriculture as well as public health in India. One of the best ways to manage the pernicious weed might be its self-utilization as compost, green manure or mulch in crop areas.

In this view, a field experiment was conducted during 2008-09 and 2009-10 at 'C-Block' (Incheck) Farm, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal in a RCB design with three replications. Three levels of nutrients *viz.* NPK at recommended dose + green manuring of *Parthenium* (before flowering) at 5 t/ha, NPK at recommended dose + mulching of *Parthenium* (before flowering) and its subsequent incorporation at 5 t/ha, and only NPK at recommended dose were applied in three commonly farmers' accepted crop sequences (pre-*kharif*, *kharif* and *rabi*) *viz.* Black gram - Transplanted rice - Onion, Sesame - Transplanted rice - Chickpea, and Okra - Transplanted rice - Rapeseed under medium land situation having good irrigation facilities. All the crops in respective sequences were raised with recommended package of practices. Data were recorded on soil fertility status (available nitrogen, available phosphate and available potash content in soil before and after crop sequence) as well as system productivity (Rice Equivalent Yield, REY). Correlation studies were made between nutrient level and REY of different crop sequences.

Application of NPK at recommended dose along with either green manuring (8.21 t/ha) or mulching (7.76 t/ha) significantly improved overall system productivity (REY) under the crop sequence of Black gram - Transplanted rice – Onion possibly due to better nutrient availability with the addition of *Parthenium* as organic manure in soil. The next best crop sequence was Okra - Transplanted rice – Rapeseed, exhibiting higher productivity with the application of recommended NPK + green manuring (6.82 t/ha) *fb* recommended NPK + mulching and incorporation (6.24 t/ha) and only recommended NPK (5.92 t/ha). There was also a significant increment of soil availability of nutrients (available N, available P_2O_5 and available K_2O) due to combined application of recommended NPK + green manuring (23.8-24.6, 39.5-48.5 and 41.8-43.6%, respectively), *fb* recommended NPK + mulching and incorporation (17.8-19.2, 27.2-32.8 and 30.9-32.7%, respectively) at the end of third cropping season over the onset of first cropping season, irrespective of crop sequences. Yield advantages were found to be significantly correlated with different nutrient levels.

The present study revealed the vast possibilities of utilizing *Parthenium* at vegetative stage (before flowering) either as green manure or as mulch with a view to improve soil fertility as well as crop productivity under potential crop sequences (Black gram / Okra - Transplanted rice – Onion / Rapeseed), besides keeping the weed under appropriate suppression for the state of West Bengal.

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Eco-friendly weed management options under organic production system

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Farmers around the world realized the adverse effects of modern agriculture and started their own efforts to develop a sustainable system which is now recognized as organic farming. There is an emerging awareness among public on the use of high quality food materials which are free from chemical toxicants. At present, the concept of organic farming gaining importance and there exist a greater demand for residue free organic products. Organic weed management encourages weed suppression rather than elimination through managing weed population below economic threshold level by appropriate combination of weed management practices like physical, cultural, biological and integrated weed management which results in eco-friendly weed management. Weed suppression in organic farming is done by promoting soil health through a combination of crop rotation, cover crops, biologically based bio-fertilizers, compost and mulch. Proper weed management through organic methods offers varied benefits over chemical herbicides including increased biodiversity, improved soil nutrition, soil structure and protection of ground and surface water. Successful weed management requires identifying relevant species and understanding their biological characteristics so that management can be tailored to the weeds present in individual fields. Accurate identification is critical and identification of seedling weeds is necessary for selecting an appropriate weed management practice and also considering the diversity of weed problem and agro-ecosystems, no single method, whether manual, mechanical or chemical provides the desired level of efficiency under all situations. Hence integrated weed management is the best tool for effective weed management under organic production systems.

Non chemical weed management: sustainable tools, tips and techniques in organic farming

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This paper gives an overview of the sustainable tools, tips and techniques used in organic farming worldwide. The term *"weed"* has been defined as a *"plant out of place,"* an *"unwanted plant"*. Weeds do not always disadvantageous but offer some welfares in terms of biodiversity. Overall weeds perform a number of vital ecological functions. On the other hand, weeds hurt crop yields, reduce quality of food, increase cost of production in organic farming.

According to International Federation of Organic Agricultural Movements (IFOAM) organic agriculture can be as defined as *"a sustainable production system that that considers the health of soil, ecosystem, biodiversity, fairness, care and good quality of life for all involved"*. It combines tradition, innovation and science to benefit of all concerns. Chemical intervention is not permitted for weed control purposes in organic farming systems.

Weed management and control is a critical issue, rises on the top of the problem list of organic farmers. There is no one "silver bullet" technique for weed control in organic farming like conventional agriculture. Timing and control speed along with feed water schedule matter in weed management. Presently, demands for organic food and the profile of organic farming have increased, so as to the weed control strategies/ options. Certified organic foods usually receive higher selling prices than that of non-organic foods. Weed management is a challenging task for organic farmers, remains a significant barrier to optimize crop yield, quality and the cost of production.

Organic farmers adopt a wide variety of tools and strategies to control weeds without artificial chemicals. The philosophies and legalities of organic farming must be understood before planning weed management tactics. Emphasis has to be given for a combination management practices to control weeds; like *weed ecology knowledge, cultural methods, crop rotation, mechanical weed control techniques, mulching and herbicides, etc.* for optimum results and economic sustainability. Herbicides are central and finishing strategy to control weeds that allowed the farmer to reduce time, effort and cost.

This paper summarized the pros and cons, tips and tools, methods and techniques for non-chemical weed management in organic farming. A comparative study has been carried out and put forward some suggestions as results. Here, special attention has been given to the *Thermal Weed Control Methods*; including flaming, hot water, hot foam, steaming, hot air, electrocution, infrared radiation, microwave, laser radiation, *etc.* A comparative study has been presented considering benefits and limitations of these thermal techniques. This paper illustrates the 12 tips/steps to be taken for non-chemical weed management in organic farming. The outcome of these paper will benefit organic farmers and researchers working in sustainable organic agriculture.

Flaming: A weed control option in organic agriculture

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Repeated use of herbicides resulted in increasing number of herbicide-resistant weeds, shifts in weed species population, higher cost of chemical control measures, leaching of herbicide into ground water as well as accumulation of herbicide residues in drinking water and food, which have sparked public awareness resulted in restrictions on herbicide use. Flame weeding is an alternative weed management practice in organic agriculture. Propane-fueled flame weeding is an acceptable weed control option and has received renewed interest among the farmers for both organic and conventional cropping systems. Sixty kilograms of propane per hectare was the most effective field application dose to control several annual broad-leaf weeds and many grasses. Flaming controls weeds primarily by rupturing the cell membranes that leads to subsequent tissue desiccation. Propane burners can generate combustion temperatures of upto 1900 °C, which raises the temperature of the exposed plant tissues rapidly. An increase of temperature to >50 °C inside the plant cells can result in the coagulation of membrane proteins leading to loss of membrane integrity. Flame weeding is widely used in organic farming for post-emergence control in slow-germinating heat tolerant row crops. The efficacy of flame weeding was reported to be influenced by several factors including growth stages of the plant, the physical location of the growing point at the time of flaming, the presence of protective layers of hair or wax and lignifications, the technique of flaming, the regrowth potential of plant species and the leaf relative water content of plant species. Flame weeding has some major advantages over herbicide application. It is an attractive weed control option because it leaves no chemical residues in plants, soil, air, or water, produces no drift hazards or herbicide carryover to the next season and can control herbicide-tolerant or resistant weeds. Flame weeding is less expensive than hand weeding and organic herbicides and there is no chance of weeds to developing resistance by the weeds to high level of instant heat produced by flaming torches. The disadvantages of flame weeding compared to conventional herbicides include higher cost of equipment compared to herbicide applicators, lack of selectivity for crop safety and low speed of application.

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Evaluation of non-chemical weed control methods in direct-seeded rice under rainfed condition of Nagaland

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A field experiment was conducted in the experimental farm of School of Agricultural Sciences and Rural Development (SASRD), Nagaland University, Medziphema campus during *Kharif* season of 2017, to evaluate the effect of non-chemical weed control methods in direct-seeded rice (*Oryza sativa* L.) under rainfed condition of Nagaland. The Agronomy research farm is located in the foothill of Nagaland. The geographical position of the farm lies at $25^0$45’43" North latitude and $95^0$53’04" East longitude at an altitude of 310 meter above mean sea level (MSL). The experiment was laid out in a randomized block design (RBD) with three replications and eight treatments. The different treatments consisted of; weedy check, weed free, farmers’ practices (common salt at 150 kg/ha), stale seedbed technique, stale seedbed technique followed by 1 HW at 25 DAS, stale seedbed technique followed by brown manuring (*Sesbania rostrata*), brown manuring and bispyribac sodium salt at 25 g/ha (herbicidal check). *Eleusine indica* was found to be the highest relative composition among the weed species at all crop growth stages. The reason might be due to high favourable growth factors. The pre-dominant grass weeds were *Eleusine indica* (Gaertn), *Digitaria sanguinalis* (L), *Cynodon dactylon* (L), *Echinochloa colonum* (L.) and *Poa annua* (L), *Cyperus iria* (L.), *Cyperus rotundus* (L.) and *Fimbristylis miliaceae* (L.) were amongst sedges. *Borrerhia hispida*, *Eclipta alba*, *Commelina benghalensis* (L.) and *Mimosa spinosus* were observed amongst broad-leaf weeds in the present experimental field. The experimental results showed that the application of stale seedbed followed by brown manuring recorded lower weed population, total dry weight of weeds, weed index (12.25 %) nutrient uptake by weeds and higher weed control efficiency. The different non-chemical weed control treatments had significant effect on number of panicle/plant, length of panicle, number of effective tillers/plant and no. of filled grains/panicle at all stages of observation. The highest yield attributes were recorded from stale seedbed followed by brown manuring which was followed by stale seedbed and 1 HW at 25 DAS. Stale seedbed followed by brown manuring and application of stale seedbed followed by 1 HW at 25 DAS were at par with each other and recorded the highest grain yield and straw yield whereas the lowest was obtained in weedy check treatment. The same also produced higher plant height (117.30 cm), number of filled grains/panicle (99.47), grain yield (3.53 t/ha) and harvest index (35.40%), net return (` 31,038.83/ha) and B:C ratio (1.03) under direct-seeded rice.

Weed management in organic farming – A review

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Adoption of organic farming by farmers is limited by the concern about potential increases in weed populations without the use of herbicides. However, as public demands for organic produce in recent years has increased, so too has the range of weed control options. Cultural methods of weed control have included the use of weed suppressing cover crops, and the identification of specific crop traits for weed suppression with a goal of achieving economically acceptable weed control and crop yields. In Europe there have been increasing concerns about pesticide use in agriculture and a steadily increasing conversion to organic farming have been major factors driving research in physical and cultural weed control methods. Some of the major results achieved with non-chemical methods and strategies includes hand-weeding with mechanization. A number of investigations have focused on optimizing the use of thermal and mechanical weeding methods against weeds. Reports show that weed harrowing and inter row hoeing provide promising results when they are part of a strategy that also involves cultural methods such as fertilizer placement, seed vigor, seed rate, and competitive varieties.

A field experiment conducted in southern Swedento to investigate the efficacy of flame weeding on weed flora at different developmental stages and it was observed that plant size had a major influence on the lethal dose requirement. When flaming of weeds at early developmental stages, in split applications of two half dose treatments 1 week apart, plant numbers did not reduce effectively as a single late flame treatment with the same total dose. Although research in preventive, cultural, and physical methods have improved weed control in crops, effective long-term weed management in low external input and organic systems can only be achieved by adopting a basic principle approach, such as using cover crop and intercropping for weed suppression in a 2 year rotation.

An another field experiments was conducted to investigate the efficacy of flame weeding were conducted on a variety of natural weed flora at different developmental stages. Weed species with unprotected growing points and thin leaves such as *Chenopodium album*, *Stellaria media* and *Urtica urens* were susceptible. When these plants had 0 4 true leaves, complete kill was achieved at propane doses of 20 50 kg/ha. Species with protected growth points such as *Capsella bursa-pastoris* and *Chamomilla suaveolens* were tolerant due to regrowth after flaming, and they could be completely killed only in the early stages. *Poa annua* could not be completely killed with a single flame treatment, regardless of developmental stage or propane dose.

From the above experiment, it is concluded that plant size had a major influence on the lethal dose requirement. Propane doses of 10 40 kg/ha were required to achieve 95% control of plant numbers for sensitive species with 0 4 true leaves, while plants with 4 12 leaves required 40 150 kg/ha. When flaming naturally emerged weeds at early developmental stages, split applications of two half dose treatments 1 week apart did not reduce plant numbers as effectively as a single late flame treatment with the same total dose.

A preliminary evaluation of indigenous strain *Colletotrichum dematium* for biological management of *Parthenium*

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Parthenium hysterophorus L. is an obnoxious weed occupying vast area of cultivated land. It is of serious environmental concern because of the human and animal health hazards in most states of India. Weeds are declared diseased when they are adversely altered by pathogens. Most often pathogens are micro organisms which are frequently referred to either as causal organisms or incitants of disease to connote that they are only one facet of the tripartite biological interaction of host, pathogen and environment that is essential to disease development. Most weed diseases are incited by fungi that have the greatest potential for biological control as microbial herbicides. Periodical surveys with day-to-day contact with weeds in the field provide the best opportunity to find potentially useful weed diseases.

Therefore, the present study was carried out to find out a potential fungal pathogen for the management of the obnoxious weed, *Parthenium*. From among the different pathogens obtained during initial isolation, from strains of a potential pathogen *Colletotrichum dematium* were isolated from different localities of Jabalpur. Selected indigenous fungal pathogens *Colletotrichum dematium* (FGCN#20) was evaluated as bio-control agent for the management of parthenium. Seedling mortality and seedling blight disease of parthenium caused by four isolated of *C. dematium* (Pers ex Fr) grove, led to the preliminary evaluation of the isolate *C. dematium* (FGCN#20) as a potential mycoherbicide for the weed. This isolate was found to incite severe seedling blight leading to mortality of the entire weed population both under laboratory and natural condition. The pathogen was re-isolated from inoculated plants thus fulfilling Koch's postulated. Because of its virulence and comparatively higher disease causing ability. This isolate is selected for its development and exploitation as mycoherbicide. It is apparent from the present work that the fungal pathogens *C. dematium* (FGCN#20) has tremendous potential for development as mycoherbicide for the management of *Parthenium*. The scope of deployment and commercialization of *C. dematium* (FGCN#20) as a mycoherbicide for *P. hysterophorus* L. is treatment as this approach further gains importance in the coming year.

Effect of organic weed management practices in rice-rice cropping system

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Rice is a staple food crop that holds the key for national food security of India which contributes 43% share and also it is a source of livelihood for millions of people across the globe and earns a foreign exchange of more than ` 33000 crores. Rice is cultivated over 44 million hectares in India and 2.4 million hectares in Andhra Pradesh under diversified ecosystems. Source of organic material influences the performance of crop weed competition through its effect on growth and development. In Godavari delta, deltaic alluvial soils under canal irrigated conditions rice-rice is the most predominant cropping system. Organic farming is one of the better options to improve the nutrient availability in deltaic alluvial soil by way of improving the microbial activity in the soil. Available literature shows that, more no. of tillers/m^2 are produced in organically enriched soils.

Present investigation was carried out during *Kharif* and *Rabi, 2017-18* seasons in deltaic alluvial soils of Regional Agricultural Research Station, Maruteru to evaluate the cultural and mechanical weed management practices for Godavari delta region of Andhra Pradesh under organic production system. Experiment was laid out in randomized block design and replicated thrice with seven treatment combinations. Medium duration rice variety MTU 1075 during *Kharif* season, short duration rice variety MTU 1010 during *Rabi*, season were tested under organic weed management practices. The experimental results revealed that, location specific green leaf manure incorporation treatment recorded higher yield of 3.68 t/ha followed by locally available weed mulch + one hand weeding with 3.61 t/ha which are significantly higher than two hand weedings (3.24 t/ha) and mechanical and hand weeding once (3.27 t/ha) during *Kharif*, 2017. Whereas reduced spacing (up to 25%) + mulching with previous crop residue + one hand weeding treatment recorded lowest grain yield of 3.14 t/ha among all the treatment combinations of organic weed control methods. *Rabi*, 2017-18 season also followed the same trend of 3.59 t/ha with location specific green leaf manure treatment followed by locally available weed mulch + one hand weeding (3.41 t/ha) as like *Kharif*, 2017. But the panicle weight and straw yields could not follow any particular trend. The incidence of pests particularly leaf folder and incidence of brown plant hopper was below economic thresh hold level with the organic weed control treatment of green leaf manure incorporation treatment followed by neem cake incorporation 15 days before planting treatment. Weed index showed that, incorporation of green leaf manure controlled the weed population more effectively (20.6%) in both the seasons compared to other organic weed control treatments.

This clearly indicates that system grain yield of 7.27 t/ha was recorded significantly higher with location specific green leaf manure *i.e.*, sesbania with effective weed index of 20.6% followed by locally available weed mulch *i.e.*, water hyacinth + one hand weeding (7.02 t/ha grain yield and weed index 12.8%) compared all organic weed control treatments.

Weed density, yield and economics as influenced by non-chemical weed management and planting geometry in dry direct-seeded rice cultivars

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In the background of shrinkage natural resources direct seeded rice is best option for rice grower, but weeds are major biotic stress in this system. Chemicals are being widely used to control weed, but it create environmental pollution. A field experiment was conducted in split plot design during *kharif* season of 2015 and 2016 to study the effect of non-chemical weed management and planting geometry on weed density, yield and economics of dry-direct seeded rice cultivars. The experiment consisted of two planting geometry (Seed drill sown crop and square planting), two cultivars (Arize 6444 and PHB 71) and five non chemical weed management treatment *viz*. weedy, one hoeing at 12 DAS *fb* hand weeding at 30 DAS, one hoeing at 12 DAS *fb Sesbania* incorporation at 45 DAS, one hoeing at 12 DAS *fb* straw mulching at 4 t/ha *fb* hand weeding at 40 DAS, one hoeing at 12 DAS *fb* straw mulching at 6 t/ha. Result revealed that square planting recorded lower weed density, higher grain yield (4.08 and 4.29 t/ha) and B: C ratio (1.03 and 1.14). Among cultivars, Arize 6444 cultivar also recorded lower weed density, higher grain yield (4.13 and 4.36 t/ha) and B: C ratio (1.04 and 1.15). However, among weed control measures, one hoeing at 12 DAS *fb* hand weeding at 30 DAS weed management practice reduced weed density and increased grain yield (4.76 and 4.93 t/ha) while B:C ratio was maximum (1.59 and 1.71) in one hoeing at 12 DAS *fb Sesbania* incorporated at 45 DAS treatment during both the years. Lower weed index was recorded in square planting treatment and PHB 71 cultivar. Amongst weed management, minimum weed index was recorded in one hoeing at 12 DAS *fb Sesbania* incorporated at 45 DAS treatment in respect of one hoeing at 12 DAS *fb* hand weeding at 30 DAS treatment where minimum weed competition was observed. While, higher weed index was recorded in weedy plot in which maximum weed competition was occurred. On the basis of result square planting with Arize 6444 cultivar and one hoeing at 12 DAS *fb* hand weeding at 30 DAS or one hoeing at 12 DAS *fb Sesbania* incorporated at 45 DAS treatment reduce density and increase productivity and profitability of direct seeded rice system.

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Integrated Management of Congress grass (*Parthenium hysterophorus* L.)

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Congress grass, *Parthenium hysterophorus* L. belonging to family Asteraceae commonly known as carrot weed and gajar ghans in hindi is an invasive weed species in Africa, Australia and Asia. It is a native of tropical and sub-tropical South and North America. The weed was accidentally introduced to India in 1955 through imported food grains and at present has invaded throughout India in about 35 million hactares of land. The lightness of the seed, prolific seed production, adaptability to wide range of habitats, drought tolerance, its ability to release toxic chemicals against other plants, and its high growth rate allows it to colonize new areas quickly and extensively. This noxious weed is often spotted on abandoned lands, developing residential colonies around the towns, railway tracks, roads, drainage and irrigation canals, *etc.* This weed grows luxuriantly in established gardens, plantations and vegetable crops. Due to its high fecundity a single plant can produce 10,000 to 15,000 viable seeds and these seeds can disperse and germinate to cover large areas. It affects human health causes skin diseases and allergic reactions, also affect livestocks and reduces yield of agricultural crops in the affected field. The weed suppresses growth of local vegetation and has been reported as a health hazard for farm laborers causing dermatitis, eczema and asthma. The weed is also a reservoir of tobacco leaf curl virus, mung yellow mosaic and okra yellow vein mosaic virus, groundnut and sunflower bud necrosis, tobacco streak virus and tomato leaf curl virus. The aim of this review is to provide general information about the weed, distribution, ill effects, and management of *Parthenium*. There are many ways, physical, chemical, and biological to control it but it cannot be controlled by using a single approach. Successful management of this weed can only be achieved by an integrated approach with biological control by *Zygogramma bicolorata* Pallister (Coleoptera: Chrysomelidae) as the key element. Biological control of *Parthenium* is the most cost-effective, environmentally safe and ecologically viable method. The Mexican beetle was imported into India in 1983 for the biological control of the noxious *Parthenium* weed, Grubs and adult beetles feed voraciously on the foliage and inflorescence and were mostly confined to congress weed.

Feeding potential of Mexican beetle, *Zygogramma bicolorata* P. under laboratory conditions in Raipur district of Chhattishgarh

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Congress grass, *Parthenium hysterophorus* L. belonging to family Asteraceae commonly known as carrot grass and gajar ghans in hindi is an invasive weed species in Africa, Australia and Asia. It is a native of tropical and sub-tropical South and North America. The weed was accidentally introduced to India in 1955 through imported food grains and at present has invaded throughout India in about 35 million hactares of land. The lightness of the seed, prolific seed production, adaptability to wide range of habitats, drought tolerance, its ability to release toxic chemicals against other plants, and its high growth rate allows it to colonize new areas quickly and extensively. It affects human health causes skin diseases and allergic reactions, also affect live stocks and reduces yield of agricultural crops in the affected field. Both grubs and adults feed voraciously on the leaves and has the capacity for total defoliation of the plants leading to death of young plants. Life cycle of *Zygogramma bicolorata* Pallister indicates four larval (grub) instars with and adult longevity of an average 30- 65 days. Keeping this fact in view the feeding potential of Mexican beetle, *Z. bicolorata* Pallister was conducted under laboratory conditions, Department of Entomology, IGKV, Raipur district in Chhattisgarh during 2018. For this purpose an experiment was conducted on potted plants covered with nets. Twelve plants belonging to three stages of *Parthenium* plants *i.e.* early stage, pre-reproductive (before flowering) and reproductive (after flowering) were planted and by releasing, two, three, four and five pairs of *Z. bicolorata* adults replicated thrice. Observations were recorded on the feeding potential of Mexican beetle on three age stages of *Parthenium.* On the basis of all over mean time taken (in days) of the current year's the data indicated that feeding efficiency of *Z. bicolorata* on different age of host plant *i.e.* early stage, pre-reproductive and reproductive treatments differed with each other. The lowest time taken (4.66 days) for complete defoliation was by five pairs of Mexican beetles followed by three pairs (13.66) and highest in two pairs (17.00 days) on early stage of the plant. The damage inflicted by *Z. bicolorata* was more pronounced when the beetles were released in higher density and at early growth stages of the weed.

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Use of soil micro organisms for weed management

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Ecological approach of weed management has been an area of interest as an alternative to conventional weed management. Soil microbial community is an important part of any agroecosystem. Micro organisms are responsible for many functions in soil from nutrient cycling and residue decomposition to maintenance of soil structure and plant health. Micro organisms in soil may have either beneficial or detrimental effect on plant health. Detrimental effects are due to plant suppressive compound, decreasing plant available nutrient and causing plant diseases. Therefore survival and elimination of any plant species are greatly affected by micro organisms in their ecosystem. By incorporating the knowledge of soil microbial and other biological properties we can increase input use efficiency and decrease the dependence on synthetic chemical herbicides. Majority of biological control agents developed and studied like Devine™ Collego™ and BioMal™ attack the developing plant rather than seeds. However, one category of micro organisms largely neglected as biological control agents of weed include deleterious rhizobacteria (DRB) which colonize the root surfaces and are able to suppress the plant growth. Generally DRB are non-parasitic bacteria which can reduce weed menace in field by producing some allelochemical in the rhizosphere such as include i) antibiotic production ii) IAA production iii) ALA production iv) production of other secondary metabolites v) phytotoxin production vi) siderophore production. Some rhizobacteria are specific to certain plant and therefore can be exploited as biological weed management measures. On the other hand, multiplication and survival of DRB are greatly affected by soil physical and chemical properties like soil temperature, soil moisture, soil structure and texture *etc.*; soil biological properties such as secretion of root exudates of plants, soil organic matter content; and environmental factors. Therefore understanding the crop ecology in context of soil microbiology is a key for successful use of DRB in weed management programmme. The practical approach is selection of such soil micro organisms, application of their culture in soil to increase their population thus manipulating the rhizospheric environment to achieve rapid growth suppressive activities. Although DRB approach may seem less efficient than herbicides as their mode of action is mainly through growth suppression rather than killing the plants, they can prove a crucial part of Integrated weed management strategy since purpose of integrated weed management is in fact more than mere weed control and more profit in financial terms; and that is to sustain the ecological balance of the crop field, reduce the resistance development in weeds to intensively used herbicides, broad spectrum control of weeds with least chemical exposure to our environment *etc.* Use of host specific DRB in IWM can reduce early weed pressure on emerging crop by weakening the weed seed germination and weed seedlings and allow the crop development to take an early edge over the competing plants of the field *i.e.* weeds. Most studied deleterious rhizobacterium has been *Psuedomonas fluorescence* which was first reported to be effective on downy brome (*Bromus tectorum*) and thereafter on several weeds like foxtail *etc.* Geldanamycin obtained from *Streptomyces hygrocopicus* showed pre-emergence activity on proso millet, barnyard grass, garden cress and giant foxtail. Similarly *Pseudomonas syringae* pv. Tagetis has been found as another promising biocontrol agent. Thus, there is a great scope for use of rhizobacteria as a component of multiple methods of weed control to combat the developing herbicide resistance and weed flora shift in agroecosystems.

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Biological management of invasive alien weed, *Mikania micrantha*

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Mikania micrantha is a perennial climber from tropical America. It is a major invasive in several parts of south-east Asia including India. It was introduced in India in the 1940s as ground cover in tea plantations and now it became a threat to the plantation crops and forest area of the nation. So, its management is a very important aspect in plantation crops.

Some of the soil microbes add successful resistance to native plant species against any invasive plant. In the presence of pathogenic soil fungi in rhizospheric soils of native tree species of China like *Heteropanax fragrans*, *Cinnamomum burmanii* and *Macaranga tanarius* were effective in controlling the notorious vine *Mikania micrantha* (Lei *et al.* 2013). *Puccinia spegazzinii*, the rust pathotype from Trinidad was first released in tea gardens of Assam in India for control of the invasive alien weed, *Mikania micrantha*, but did not establish on the weed, probably due to the presence of a partially rust resistant biotype of the weed. However, in Kerala, the rust has spread and is persisting in agricultural systems and forest sites and was the first instance of using a fungal pathogen as a biocontrol agent against *Mikania* weed. This species causes necrosis and canker in all the aerial parts of the plant and ultimately kills it (Ellison *et al.* 2008 and Kumar *et al.* 2007). Lepidopteran defoliator *Actinote thalia pyrrha* (Fabricius) larvae, tea mosquito bug (*Helopeltis theivora*) are also successful biocontrol agent against this weed.

Some of case studies in China revealed that three parasitic *Cuscuta* spp. have potential use in controlling aggressive invasive weed, mile-a-minute. This obligate parasitic plant negatively influenced and significantly reduced the growth, total biomass, stomatal conductance, transpiration and net photosynthetic rate and biomass allocation patterns in addition to complete inhibition in flowering of the infected invasive weed. There was decrease in relative growth rate, unit leaf rate and leaf area ratio after parasitization (Shen *et al.* 2005).

Tall grasses were found to decrease biomass of *Mikania micrantha* to a great extent. Different favourable characteristics of grasses are tall stature, long, elastic leaf blades or stalks on which the vine could not grasp and climb. *Panicum maximum* and *Pennisetum purpureum* can reduce biomass of mile-a-minute at least 88.9 and 75.0%, respectively (Zhou *et al.* 2016).

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Impact of *Parthenium hysterophorus* on the diversity of Chitrakoot and its biological control by *Zygogramma bicolorata*

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Parthenium hysterophorus is an aggressive and hazardous weed causing harm to biodiversity of natural plant communities, humans and animals. In agriculture fields, *Parthenium* weed releases allelopathic chemicals mainly parthenin, which show high competitive ability for soil moisture and nutrients. The germination and growth of other important crops and other plant species were affected by *Parthenium.* Ecological impact and economic loss due to rapid expansion of *Parthenium* has become a regional environmental issue of tropical world. It threatens biodiversity by competing with crops, other useful weeds and indigenous plant species or resources. *Parthenium* weed affected biodiversity by displacing the native as well as exotic species and medicinal plants. Biological control efforts on *Parthenium* in India have gained momentum after the limitation of other methods is realized. Native surveys revealed a large number of insects, but none of them was host specific. Although mexican beetle *Zygogramma bicolorata* has established at the sites of initial released.

In the present observation, the incidence, density and distribution of *P. hysterophorus* were carried out along with the biocontrol by *Zygogramma bicolorata*. *Zygogramma bicolorata* Pallister was released into Bangalore from Mexico in 1984. *Parthenium hysterophorus* dispersed over 50000 km^2 by 1992. The beetle appears to have potential in reducing weed density in those parts of India having moderate weather condition. Its occurrence and distribution was studied around the local areas of Chitrakoot. *Z. bicolorata* was introduced to India as a bio control agent for the weed *Parthenium hysterophorus*. During field survey of different *Parthenium hysterophorus* growing areas of Chitrakoot in 2015-18 in search of natural enemy of this weed. During survey both adults and larvae of Mexican beetle *Zygogramma bicolorata* were found feeding on leaves. Immature flowers were cut by the beetles. They chew the soft tissues beneath the flowers and defoliated completely. *Zygogramma bicolorata* is an effective biocontrol agent that can significantly reduce the vegetative and reproductive growth of *Parthenium* weed. However, the effectiveness of the biological control *Z. bicolorata* can be further enhanced if it is applied at pre-flowering stages of Parthenium weed. It is found as a promising, safe, eco-friendly biocontrol agent. Its distribution among farmers can also help in the control of *Parthenium hysterophorus* in their fields. Biological control programs have saved millions of dollars and despite the high initial costs. Thus it is very cost effective also.

Allelopathy: A potential tool for weed management in sustainable agriculture

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The sustainability of agriculture relies on the development of strategies that lower the need for costly external inputs and minimize detrimental effects on the environment, which often involve either inappropriate or excessive use of agrochemical inputs. Allelopathy is defined as the ability of plants to inhibit or to stimulate growth of other plants in the environment by chemical means. Agriculture integrated with allelopathy could reduce the heavy dependence on synthetic herbicides and other agrochemicals, and therefore ease problems such as environmental contamination. The allelopathy may be management in crop rotation, preceding and cover crops, green manure, mulch, and intercropping, and the incorporation of allelopathic plants in soil.

Under appropriate conditions, allelochemicals exhibit selectivity, similar to synthetic herbicides. Two main approaches have been investigated for allelopathic weed suppression. One is use of living rotational crops or mulches that interfere with the growth of surrounding weeds *eg. Festuca amndinacea*, *Festuca rubra, Asparagus officinalis, Sorghum bicolor, Medicago sativa, Brassica nigra, Avena sativa etc*. *Secale cereale, Sorghum bicolor, Oryza sativa, Helianthus annus, Brassica napus* and *Triticum aestivum* have been documented as important allelopathic crops. These crops express their allelopathic potential by releasing allelochemicals which not only suppress weeds, but also promote underground microbial activities. Further, several types of allelopathic plants can be intercropped with other crops to smother weeds. The second is use of cover crop residues or living mulches to suppress weed growth for variable lengths of time. Cover crop residues may selectively provide weed suppression through their physical presence on the soil surface and by release of allelochemicals or microbially altered allelochemicals. Rotating a routine crop with an allelopathic crop for one season is another method of allelopathic weed control. Khalique *et al.* in Pakistan (2010) applied a combination of allelopathic plant residues including sunflower, canola and sorghum at 7.5 ton/ha for weed control in maize. The applied mulch reduced the densities and biomass of *Cyperus rotundus* and *Trianthema portulacastrum* by 90% and increased grain yield, 1000 grain weight, harvest index by 54%, 13%, 29% respectively. Bernstein *et al.* (2014) tested efficacy of rye cover crop to suppress weeds for planting soybean under no till condition. Planting soybean in standing rye cover crop resulted in long lasting and effective weed control with no damage caused to soybean.

Among different biological methods of weed control, allelopathy could lead to reduced labour costs and increased efficiency, without any adverse effects on the environment. Integrating allelopathy as a biological control method is helpful for alleviating the interference of weeds, and maintaining an eco-friendly environment. A diversity in weed management tools ensures sustainable weed control and reduces chances of herbicide resistance development in weeds. Allelopathy as a tool, can be importantly used to combat the challenges of environmental pollution and herbicide resistance development. Hence allelopathy has a pertinent significance for ecological, sustainable, and integrated weed management systems.

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Elevated CO_2 and temperature linked based population dynamics and biocontrol efficiency of *Zygogramma bicolorata* Pallister (Coleoptera: Chrysomelidae)

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Climate change is happening at a rapid pace around the globe which is significantly impacting the plant growth and ecosystem dynamics. The rising concentration of atmospheric carbon dioxide (CO_2) is also contributing towards global warming. *Parthenium* weed infests several major crops including wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), rice (*Oryza sativa* L.), sorghum [*Sorghum bicolor* (L.) Conrad Moench] and sugarcane (*Saccharum officinarum* L.). *Parthenium* weed is likely to demonstrate an increased growth rate in a climate enriched with CO_2 and increased temperatures. Six circular type open top chambers (OTCs) 5.55 m^2 were conducted at ICAR-Directorate of Weed Research, Jabalpur. After germination of *parthenium* weeds at 15 pairs *Zygogramma* beetles were introduced in equally in each chamber except in control chamber. Total number of egg laying per plant, total grubs per plant and total adults per plant were counted per week of the month. At harvesting time, three plants of blackgram were separated from each chamber for yield calculation. In resulted leaf nitrogen content was distinctly lower in elevated CO_2 foliage. In contrast, carbon content was higher in elevated CO_2 foliage. Consequently, the change the relative proportion of carbon to nitrogen (C: N ratio) was considerably higher in elevated CO_2 foliage. Elevated CO_2 foliage had higher polyphenol content too, compared to ambient CO_2. Mean population counts revealed that maximum population (62 and 77 adults/plant) of *Zygogramma bicolorata* was observed during 6th and 7th weeks in elevated CO_2 and 7th to 8th week increased population in elevated CO_2 and elevated temperature. In only elevated temperature chamber population of *Z. bicolorata* was 6th to 7th week but Ambient chamber *Z. bicolorata* population were increased 8th to 9th weeks (39.4 and 68.5 adults/plant). Observation of yield of blackgram was higher with introduce *Z. bicolorata* in case of elevated CO_2 and elevated temperature 0.66 t/ha, 0.59 t/ha in only elevated temperature, 0.69 t/ha in only elevated CO_2 and 0.56 t/ha in ambient chamber. Without *Z. bicolorata* yield was calculated in ambient chamber 0.47 t/ha.

Effects of *e*CO_2 and *e*Temperature on *Zygogramma bicolorata* reared on parthenium weed, *Parthenium hysterophorus*

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Mexican beetle, *Zygogramma bicolorata* Pallister (Coleptera: Chrysomelidae) is a potential carrot grass, *Parthenium hysterophorus* weed controlling bioagent. Its grubs and adult fed on the leaves and flowers of *P. hysterophorus* causing heavy damage to the plant. Controlled condition experiments were conducted to understand the direct and indirect effects of elevated temperature and CO_2 through host mediated effect on *Z. bicolorata*. Food consumption, utilization, ecological efficiency and life table parameters of *Z. bicolorata* were studied in grubs and adults stage up to diapause. Reduction of leaf nitrogen in *Parthenium* foliage with increased carbon and C: N (11.69%) at *e*CO_2 over a CO_2 indicated the dilution of biochemical constituents in host plant. Significant effect of elevated CO_2 and temperature on *Z. bicolorata* was observed, such as longer growth duration of eggs, grubs and pupa with high consumption of parthenium foliage by *Z. bicolorata* grubs and adults under elevated CO_2 and temperature compared with ambient conditions. Elevated CO_2 and temperature also had a significant effect on the intrinsic rate of increase (R), finite rate of increase (ë), net reproductive rate (R_0) and gross reproductive rate (GRR). The values of these parameters were at low at *e*CO_2 and *e*Temp treatments compared to ambient. The present study results showed that *e*CO_2 and *e*Temp levels changed the quality of the parthenium leaves which results to increase the consumption, slower growth, longer developmental period with reduced reproduction efficiency which all indicating that feeding and reproduction efficiency of *Z. bicolorata* is likely to be reduced in future climate change scenarios.

Effect of elevated CO_2 and temperature on biology of *Zygogramma bicolorata*

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In the future, the excess amount of atmospheric carbon dioxide and temperature will have very positive effect on invasive weed of parthenium about its quantity and properties, which will have a direct impact on the life cycle of the *Parthenium* bioagent *Zygogramma bicolorata*. Elevated carbon dioxide and elevated temperature effects direct on fecundity, survivality, time of pre-oviposition, egg laying time, hatching percentage, larval development duration, pre-pupal time, percentage of soil entering for pupation, emergence percentage and sex ratio value. Currently we are investigation of potential of *Z. bicolorata* on *Parthenium* eradication under elevated carbon dioxide and elevated temperature because climate change will have a considerable impact upon the processes that moderate weed invasion, in particular to that of parthenium weed (*Parthenium hysterophorus* L.). Experiments were carried out during rainy season in six circular type open top chambers (OTCs) 5.55 m^2 were conducted ICAR-Directorate of Weed Research, Jabalpur, one for maintaining only elevated CO_2, one for elevated CO_2 and elevated temperature, one for only elevated temperature and ambient CO_2, one for maintaining ambient CO_2 and ambient temperature, other hand two for maintaining as a control experiment. Results were clearly indicated that the very good potential achieved *Z. bicolorata* in elevated CO_2 and elevated temperature in case of high fecundity, good hatchability, quality larval survivality, best pupation percentage, excellent emergence percentage and good longevity of adults fallowing only elevated CO_2, only elevated temperature compared to ambient CO_2 and ambient temperature. Leaf nitrogen content was distinctly lower in elevated CO_2 foliage. In contrast, carbon content was higher in elevated CO_2 foliage. Consequently, the change the relative proportion of carbon to nitrogen (C: N ratio) was considerably higher in elevated CO_2 foliage. Elevated CO_2 foliage had higher polyphenol content too, compared to ambient CO_2. We are concluded that in the only elevated carbon dioxide, *Z. bicolorata* was exhibited lower performance similar was showed in the only elevated temperature because lower nitrogen content found there which necessary element for the development of beetles but both elevated CO_2 and elevated temperature, *Z. bicolorata* was displaced moderately good potential about survivality and fit for near future over minimize of parthenium population in India.

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Plant pathogens as agents of biological control of weeds

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Global agricultural productivity is affected due to increasing unwanted plants in the form of weed flora that adversely affect crop growth and development and also reduce crop yields. Whereas, currently available herbicides sometimes do not provide proper control of weed flora and also weeds are developing possible resistant strains against herbicides. Weed flora may act as hosts for pathogenic organisms and many plant pathogens have been documented as one of several possible means of controlling the weeds by researchers in India or elsewhere. Biological control of most problematic weed flora from pathogenic organism may be explored in the near future as alternative source of integrated weed management. Recently the successful introduction of the first plant pathogen, *Puccinia spegazzinii*, against mikania weed (*Mikania micrantha*) has been achieved in India. It is envisaged that more introductions will be made in the future. The agents under consideration are *Puccinia abrupta* and *Partheniicola parmelee* against parthenium weed (*Parthenium hysterophorus* L.), generally considered as the worst terrestrial weed in India. Other terrestrial weeds such as *Chromolaena odorata* and *Lantana camara* L. and aquatic species like *Eichhornia crassipes* (Martius) Solms-Laubach could be targeted for pathogens. Impressive control of *O. stricta* and the related *Opuntia elatior* Miller is first successful intentional use of an insect to control a weed in India. Unconfirmed reports suggest that *P. abrupta* var. *partheniicola* also occurs at lower elevations in India, but it is not a common pathogen of the weed. In this context of controlling weeds and otherwise invasive plant species has increasingly focused on bacteria, fungi and virus in the last five decades. Many fungi have been available for biological control of weeds like a formulation of *Colletotrichum gloeosporioides f.* introduced for the control of round leaf mallow (*Malvapusilla*) and *C. gloeosporioides f.* sp. *aeschynomene*, which was released for the control of northern jointvetch (*Aeschynomene virginica*) in United States. In addition to several other species within the genus *Colletotrichum* have been investigated, including *C. truncatum* to control hemp sesbania (*Sesbania exaltata*) and *C. orbiculare*, its potential to control spiny cocklebur (*Xanthium spinosum*). *P. macrostoma* is also able to specifically inhibit the growth of dicot plants *Pseudomonas fluorescens* strain D7 bacteria, isolated from the rhizospheres of winter wheat (*Triticum aestivum*) and has been observed to selectively inhibit growth and germination of a number of grassy weeds, most notably downy brome. Conversely, *P. fluorescens* strain WH6 affect the germination of a much broader range of plant species, significantly inhibiting germination of all species tested (21 monocot species and 8 dicot species) with the exception of a modern corn (*Zea mays*) hybrid. Many viruses have able potential to control invasive or undesirable species, include Tobacco Mild Green Mosaic Tobamovirus for control of tropical soda apple (*Solanum viarum*) in Florida and Araujia Mosaic Virus for control of moth plant (*Araujia hortorum*) in New Zealand. Biological control of weed flora has better option to organic production systems in near feature. With continued investigation in this field, there is significant potential for the development of new weed control strategies to maintain consistent efficacy in field conditions.

Development of double axial transverse rotary mechanism for crop residue cutting, shredding and weeding

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Practice of conservation agriculture is well known in India but its adoption is very low particularly in rainfed agriculture. Weeding and crop residue management are two important aspects in conservation agriculture for which appropriate farm equipment are required. Usually, crop residues can be recycled either by incorporating them into soil for enhancing decomposition or placing on the surface as a mulch. Methods of weeding and crop residue mulch with minimum soil disturbance have greater importance in conservation agriculture. Considering the importance of weeding and crop residue mulch in conservation agriculture point of view the project was envisaged to develop double axial transverse rotary mechanism anticipating that there would be a minimum soil disturbance without compromising cutting efficiency, shredding efficiency and weeding efficiency. The prototype was developed and tested at Farm Machinery Research Workshop, Central Research Institute for Dry land Agriculture (CRIDA), Hyderabad during 2016-17. Experiments were conducted with sorghum stalk to finalized critical parts such as blade, rotor length, rotor speed, forward speed for development of prototype. Prototype has two cylindrical rotors having triangular edged tooth plates on its periphery rotating in opposite directions in plane. The rotational speed of cylinders was 450 rpm and suitable for 3km/h travel speed of tractor. The machine was tested in field conditions for sorghum, maize, castor and red gram crop stem cutting and shredding, and weeding. The cutting efficiency of finalized model for sorghum, maize, castor, red gram was found to be 94%, 81%, 72%, and 68% respectively. The shredding of finalized model for sorghum, maize, castor and red gram was found to be 69%, 61%, 46%, and 41% respectively. The performance of prototype in terms of cutting and shredding efficiency was found to be superior for 25% stem moisture compared to 45% and 65% stem moisture and it was true in all the crop studied. The weeding efficiency of newly developed model was comparatively lower it disturbed only one inch soil depth as against 1.5 - 2.0 inch soil depth which indicated that the soil disturbance for per unit area was about 33-50% less when weeding was done with newly developed rotary tiller. Overall, the prototype was found to suit the theme of conservation agriculture.

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Potential of leaf and root extracts of endangered Himalayan medicinal herb *Valeriana jatamansi* Jones for crop protection

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Himalaya contributes to the fame of therapeutically important medicinal and aromatic plant biodiversity. Majority of the medicinal plant species are endemic to Indian Himalayan region. Antibacterial and antioxidant activities are the key properties of medicinal plants due to which over harvesting of these medicinally important plants are more vulnerable to extinction. Slow growth rate, low population density, narrow geographic range and habitat degradation are the major reasons for the depletion of *Valeriana jatamansi* from its natural habitat. Numerous studies have been done in *Valeriana jatamansi* for therapeutically important bioactive compounds and their uses in medicine, agriculture and industry. Studies on medicinal plant have consistently demonstrated that non-protein nitrogen compounds (flavonoids, tannins, phenolic acids, stilbenoids and lignans) produced by the plant to protect it against environmental stress.

Protein content was estimated by Bradford's (1976) method in different plant parts *viz.* leaf, root, stem and rhizome of wild plant and leaf, root and callus of *in vitro* grown cultures of *Valeriana jatamansi* since no such studies had been reported in literature. The leaf from wild source contained higher protein content (68 mg/g fresh weight) and significantly ($P<0.05$) better than *in vitro* grown leaves (38 mg/g fresh weight), similarly, wild root (46 mg/g fresh weight) showed higher protein content and significantly ($P<0.05$) better than that of *in vitro* grown roots (28 mg/g fresh weight). However, *in vitro* grown callus possessed 22 mg/g fresh weight protein content. The content of crude protein in different plant parts could be influenced by several physiological factors, plant biodiversity and would also be vary due to environmental factors.

Results indicated that protein content in *Valeriana jatamansi* was found to be lower by 100 times as compared that of higher protein rich crops *viz.* pulses (mungbean, pigeon pea, soybean *etc.*) and cereals (wheat, rice, barley, *etc.*). This could be due to channelization of nitrogenous compounds towards biosynthesis of non-protein nitrogen compounds (flavonoids, tannins, phenolic acids, stilbenoids and lignans) therefore, resulting in less protein content and more phytochemicals in medicinal plants. These phytochemicals are responsible for poor digestibility and biological utilization of protein. Further, phytochemicals interfered in mineral bioavailability by binding with nutrients. Presence of low protein content in leaf and root of *Valeriana jatamansi* might be related to high tannin content which would make insoluble complexes with protein and inhibit several enzymes of protein biosynthesis. Further, the phytochemicals like flavonoids, tannins, phenolic acids, stilbenoids and lignans would induce pathological changes in intestine and liver tissue of pests by inhibit a number of enzymes thus disturbing the metabolism.

It is envisaged that, the leaf and root of *Valeriana jatamansi* possess significant amounts of bioactive compounds. For crop protection, the optimized doses of leaf and root extracts could be used on protein rich crop system to protect their proteins from pests and reduce the risk of biotic (insects & pests) interference.

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Site specific weed management strategies for precision farming

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Conventional weed control methods mostly rely on broadcast or band application of herbicides to eliminate crop-weed competition and yield loss. Out of total quantity of herbicide applied, a large proportion is lost because of drift or evaporation, deposited on the crop or the soil and only a low proportion of herbicide reaches to target weeds. Besides, it has possible effects on human health in the form of residues in food and drinking water. The spatial heterogeneity of weeds has paved the way to study different technologies for weed detection, spatial weed management and spatial variable application of herbicides. The most readily available and sophisticated sensor for weed mapping is the human eye, but manual mapping prior to spray is time consuming and real-time manual control may not be reliable. Digital images can be captured from the ground or remotely by satellite or aircraft, but for systems aiming to treat small patches smaller than several metres, remote imagery has insufficient spatial resolution. The use of multispectral imaging sensors is able to segment the vegetation precisely from soil background and delineate the individual weed plants from the crop. A site specific weed control technology or implement acts automatically to maximize the chances of weed detection and selection of control measures in a given crop at a given growth stage at particular point of time according to predefined criteria. It requires a weed sensing system for identification and measuring weed growth parameters, a weed management model for herbicide application technology and information on crop weed competition; and a precision weed control implement for the variable application of herbicides. Several prototypes of precision weed control implements have been developed for application of herbicide droplets from micro-controlled solenoid valves, mechanical shares that rapidly enter into the soil and laser beam that cuts the weeds seems to have a signiûcant potential for accurate control of weeds. *Weed Seeker* is the commercially available spot spray system for site specific weed management. This system senses green plant biomass using a ratio of red and near infra-red reflectance if a weed is present and signals a nozzle to deliver a precise amount of chemical spraying on weed, but not on crop.

Efficiency of *Neochetina* spp. for the management of water hyacinth, *Eichhornia crassipes* (Mart.) Solms tested under laboratory conditions at Raipur, Chhattisgarh

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Aquatic weeds pose several problems to water bodies all over the world. They can be controlled by mechanical, biological and chemical methods. Mechanical and chemical methods have their own drawbacks such as the former is tedious and the latter pollutes the water bodies and injures non target fauna and flora. Biological control is the only eco-friendly, safer and non- hazardous management technique for water hyacinth. Successful attempts have been made in the past to manage water hyacinth by using the exotic weevil, *Neochetina* spp. At Raipur Chhattisgarh also the ponds were found infested with water hyacinth causing survival problems for the aquatic flora and fauna along with creating difficulties in navigation. In the present study, an attempt was made to test the efficiency of the weevil, *Neochetina bruchi* and *N. eichhorniae*. Successful control of this weed was achieved under laboratory condition when tested in plastic basins of size 15.0 x 15.0 cm in diameter. Five water hyacinth plants were taken in each basin and water was added to prevent the plants from drying. Three pair of each of the weevils were released in each basin. The setups were left undisturbed until complete feeding of plants. More than 95% of the plants dried within five months by releases of *Neochetina* spp. and the insect population increased to 8.13 adults per plant. Feeding efficiency revealed that *N. eichhorniae* scrapped more as compared to *N. bruchi* with more scrappings on the upper surface of leaves. Females scrapped more than males in both species. Sustained efforts with these insects holds out promise of control of water hyacinth in Raipur (C.G.).

Biological control of *Parthenium hysterophorus* and few other weeds of economic importance

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Parthenium hysterophorus L., an obnoxious, alien, fast growing annual weed, is a major source of nuisance, because of its ability to destroy natural vegetation and create havoc in field. Samba and Jammu districts of Jammu and Kashmir, India were surveyed intensively from May – June, 2013 onwards till August, 2018 to find out weed species infested by mealy bugs. Heavy infestation of mealy bugs were found on *Parthenium hysterophorus* at all the locations (Dhiansar, Bari Brahmana – Latitude 320 39" North and Longitude 740 53" East, Chhatha, Jammu - Latitude 320 68" North and Longitude 740 82" East, Tarore, Vijaypur - Latitude 340 09" North and Longitude 740 79" East).

During the drier months, end of May – July (23rd – 27th std. week), *P. hysterophorus*, the invasive weed species of rangelands, wastelands, bunds of cropped areas, was noticed to be heavily infested by mealy bugs, but with the onset of monsoon by end of June – July (26th – 29th std. week), rain water splashes, aid in their dispersal to shorter as well as longer distances. Symptoms of mealybug infestation on the weed become obvious, when the number of reproducing females is more. At their nymphal stage, they remain hiding on the dorsal surface of leaves or on the stem. Due to the light greenish yellow colouration at nymphal stage, they are camouflaged and so not quite visible from a distance, at the early stage of infestation. This mealybug species has the ability to increase rapidly in population size and spread to cover vast areas where host plants occur, in a relatively short period of time. Number of mealy bugs present per ten cm stem of *P. hysterophorus* was quite high (up to 170 nymphs and adults) during June – July (26th – 29th std. week). As a result of feeding by mealy bugs, the weed Parthenium completely dried up. With excessive rains however, mealy bugs population plummeted and the dried up Parthenium plants again rejuvenated. *Zygogramma bicolorata* too, appeared in good numbers on the fresh flush of Parthenium and defoliated them. At few occasions, good infestation of Cuscuta was also recorded on Parthenium, covering the whole of the plant foliage. They were also noticed to complete its whole life cycle on Parthenium, thus may play an important role in Parthenium bio-control.

Besides *Parthenium* several other weed species were also found infested with mealy bugs, *viz.*, *Amaranthus viridis* (Family – Amaranthaceae), *Cannabis sativa* (Cannabaceae), *Boerrhavia diffusa* (Nyctaginaceae), *Achyranthes aspera* (Amaranthaceae), *Euphorbia hirta* (Euphorbiaceae), *Sida acuta* (Malvaceae) and *Lantana camara* (Verbenaceae). Both mealy bugs adults and nymphs, feed on the plant by extracting sap from cells in the leaves or stems, and also secrete honey dew, resulting in development of shooty mould, giving a black sickly appearance to the *P. hysterophorus* plants from a distance.

Mealy bugs along with the other bioagents like *Zygogramma* and parasitic plants like *Cuscuta*, may act as bio-control agent in managing Parthenium and few other notorious weed species like *Lantana*, *Cannabis*, *etc.*

Theme 6

Weed management in rainfed and irrigated rice-based cropping system

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Weed dynamics in *Pokkali* ecosystem of rice in Kerala

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The coastal belt of Kerala has a unique system of rice cultivation in saline soils known locally as *Pokkali* cultivation. *Pokkali*, the most saline tolerant rice variety of the world has proved its dominance as international donor of SalTol gene as recognized by the International Rice Research Institute, Philippines. *Pokkali* system is unique in the world and was honored Geographic Indication Certificate for *Pokkali* brand rice and Plant Genome Saviour Community Award. The method of rice cultivation is also distinct that mounds are taken on dried soil during the month of April. With the onset of monsoon when the top of mounds become salt free, sprouted seeds are sown over these mounds and after one month, seedlings are transplanted by cutting and spreading these mounds along with few intact seedlings. The weed flora of *Pokkali* rice fields is different from that of other rice ecosystems. Diverse weed flora appears in low saline phase (June -November), when rice is cultivated, but they dry up and get decomposed in the high saline phase (December -May) when prawn is cultivated. Hence not much diversity in weed flora was observed and no weed management practices are being done by farmers. However, deviations in soil chemical properties like pH, EC and climatic factors like rainfall and number of rainy days has contributed to weed shifts in *Pokkali* areas. A survey was conducted in major *Pokkali* growing areas to study the weed flora in *Pokkali* ecosystem. A total of 36 weeds were identified during crop period as against 18 weed species reported in the previous study in 2004 and that included the weed flora in the actual rice fields, bunds and water channels. The weed flora consisted of seven grass weeds, six sedges, 19 broad leaf weeds and four ferns. Weeds were observed in high intensity in fields where establishment of rice seedlings were low. *Diplachne fusca* and *Eleocharis dulcis* were the major weeds. *Echinochloa crus-galli*, a dominant weed reported in earlier weed surveys was found confined to a very few locations and frequency got reduced from 80% to 12.5%. Diverse weed flora was observed at different stages of the crop. *Diplachne fusca* the major grass weed was observed in the fields and bunds since early June. During nursery stage, *Cyperus difformis and Ludwigia parviflora* dominated on the mounds which later disappeared at the transplanting stage. Aerobic condition and low salinity in the mound was replaced by submergence after transplanting which led to their absence after transplanting. However, *Eleocharis dulcis*, a highly saline tolerant sedge survived on mounds as well as main field even after transplanting. In addition, *Sphenoclea zeylanica* showed notable morphological adaptations. Aquatic and semi-aquatic weeds in field included *Monochoria vaginalis*, *Pistia stratiotes, Salvinia moletsta*, *Nymphaea nouchali* and *Eichhornia crassipes*. Along the bund, *Fimbristylis miliacea* was the major weed observed. Floating ferns like *Najas graminea* and *Hydrilla verticillata* caused problems to aeration in water in fields. Mangroves were another group of weeds found common in the bunds. The increasing weed flora and the competition imposed on crop growth thus makes weed management an important intercultural operation in *Pokkali* ecosystem.

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Weed flora association in rice varieties at varying fertility level in Himachal Pradesh

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Weeds are always found associated in agro-ecosystems. The weed flora of rice is very diverse. Rice is mainly grown in *Kharif* season and have been found infested with grasses, sedges and broad-leaved weeds. Their infestation is greatly responsible for reduction in potential rice crop yield. The genotype and fertility status of the soil mainly influence weed flora association and their diversity in a cropping system. Weed flora associated with rice under varying fertility treatments and variety was therefore investigated during *Kharif*-2018. Five fertility levels *viz*. 50% of recommended dose of fertilizer (RDF) (45:20:20), 100% of RDF (90:40:40), 150 % of RDF (135:60:60), 50% of recommended dose of fertilizer (RDF) (45:20:20) + *Azolla* at 10 DAT), 100% of RDF (90:40:40) + *Azolla* at 10 DAT and four varieties of rice Vivekdhan65, HPR 2143, HPR 2720, AZ 6508 were evaluated at Rice and Wheat Research centre, Malan during the *Kharif*-season of 2018.

Rice crop was found invaded by *Alternanthera philoxeroides* (34.1%), *Cyperus* sp. (*C. iria* and *C. difformis*, 21.5%), *Echinochloa colonum* (20.6%), *Panicum dichotomiflorum* (7.5%), *Digitaria sanguinalis* (5.2%), *Monochoria vaginalis* (5.2%), *Phyllanthus niruri* (2.6%), *Aeschynomene indica* (2.6%) and *Paspalum* sp. (0.7%). The overall average weed density was about 98 weeds/m^2. Fertility treatments brought about significantly variation in the count of *Cyperus* sp. 50% NPK remaining at par with 50% NPK + *Azolla* gave significantly lower count of *Cyperus* sp. over other treatments. 50% NPK + *Azolla* could not reduce the count of *Cyperus* over 100% NPK + *Azolla* and was superior to 100% NPK and 150% NPK. The count of *Echinochloa colona* was lower in 50% NPK being at par with 50% NPK + *Azolla* and 100% NPK + *Azolla* over other treatments. In case of *Digitaria sanguinalis* treatment 50% NPK + *Azolla* recorded minimum count which remained statistically at par with treatments 50% NPK, 100% NPK + *Azolla* and 150% NPK. Count of *Monochoria vaginalis* was significantly lower due to 100% NPK + *Azolla* followed by 50% NPK + *Azolla*, 150% NPK and 50% NPK. Weed count of *Alternanthera philoxeroides*, *Panicum dichotomiflorum*, *Phyllanthus niruri*, *Aeschynomene indica*, *Paspalum* sp. was not affected by fertility treatments. Total weed count was significantly lower due to the treatment 50% NPK + *Azolla* which remains at par with 50% NPK.

Varieties did not significantly influence species-wise weed count but total weed count was significantly affected. AZ 6508 and HPR 2143 remaining at par with HPR 2720 gave significantly lower total weed count over Vivekdhan 65. However, Vivekdhan 65 was at par with HPR 2720.

Functional validation of a novel blast resistance gene from weedy rice *Oryza rufipogon*

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Rice is one of the most important food crops produced and consumed worldwide. However, rice is being affected by various biotic and abiotic stresses. Among all the diseases affecting in rice, rice blast, caused by *Magnaporthe oryzae* is one of the most devastating diseases known to cause severe crop failure under epidemics. The weedy rice *Oryza rufipogon* having AA genome is believed to be progenitor of Asian cultivar rice (*Oryza sativa)*. Since it has long evolutionary history than the cultivated rice, it is believed that it has considerable diversity for R-genes. The *O. rufipogon* can be used as source for finding alternate and better forms of genes which can be used for rice blast management. Rathour *et al.* (2011) have mapped a new gene for blast resistance in wild species *O. rufipogon*. This new blast resistance gene was identified and genetically mapped within the 204.5 kb region on the 9th chromosome in from *O. rufipogon* accession 'WRA-21' shows broad spectrum resistance to rice blast.

To identify the resistance gene within the mapped region, resequencing of WRA21 genome using Illumina platform was carried out. A total of 10, 113, 710, 548 forward and 9, 253, 920, 238 filtered and trimmed reads obtained were further subjected to *de-novo* assembly which revealed presence of three R-genes in the mapped region, which are orthologous to previously reported *Pi5-1*, *Pi5-2* and *Pi56 R*-genes, accordingly we named these genes as *Pi5-1or*, *Pi5-2or* and *Pi56or*. The *Pi56or* encoded protein shows five amino acid substitutions, whereas *Pi5-2or* and *Pi*56or contained two and 25 amino acid substitutions as compared to their orthologues. *Pi5-1or* and *Pi56or* showed basal expression, but its induction level is increased by 10 and 17 folds at 24 and 12 h respectively post inoculation with *M. oryzae*.

We followed RNA-silencing strategy to functionally validate the resistance gene. As *Pi5-1* and *Pi5-2* genes give combined resistance, we constructed plant transformation silencing vectors to silence *Pi5-1or* and *Pi5-2or* together and *Pi56or* individually. Plant transformation of the weedy rice was carried out using Agrobacterium mediated plant transformation. Southern analysis of the putative transgenics was carried out and positive transformants were assayed for their reaction to *M. oryzae* isolate HP-23. Disease reactions were recorded on the 8th day post inoculation, The *Pi5-1or* and *Pi5-2or* silencing transformants gave resistant phenotype, whereas, the *Pi56or* transformants became susceptible in the transgenics. This validates that the broad spectrum resistance in WRA21 is governed by *Pi56or*. Thus the validated blast resistance gene *Pi56or* from weedy rice *O. rufipogon* WRA21, providing broad-spectrum resistance to *M. oryzae* can be used in rice improvement breeding programs in future.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Integrated weed management strategies in direct-seeded semi-dry rice

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Rice is the most important staple food crop of India. It is grown over an area of 42.2 million hectares with a production of 84.74 million tonnes. Inadequate availability of water supply, relatively in expensive and cost-efficient herbicides, and labor shortage at the peak of planting activities, have encouraged many rice farmers in South east Asian countries, including India to shift from transplanting to direct-seeding in irrigated areas. In semi dry seeded rice, it is sown initially in direct seeded condition under unpuddled condition and later converted to irrigated crop after the receipt of water in the canal or monsoon rains or both. The important problem in semi direct- seeded rice is weeds. Failure to manage the weeds result in 50 to 90% rice yield loss. The information available on weed management in direct seeded semi-dry rice is less or negligible in the coastal deltaic region of Karaikal, Puducherry U.T. Hence, a field study was conducted for two years (wet seasons of 2016 and 2017)at research farm of Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, Puducherry U.T. (11° 56' N latitude,79° 53' E longitude, 8 m above mean level), India. The experiment in each year was arranged in randomized complete block design with three replications. Ten treatments were included to evaluate different weed management options (pre- and post-emergence herbicides, mechanical and manual weeding) in direct seeded rice (DSR) under semidry condition. Herbicides included in the study were bispyripac-sodium, pendimethalin, oxadiargyl and chlorimuron + metsulfuron.Weed density and dry weight were recorded in two quadrats (0.5 by 0.5 m) placed randomly in each plots and the data was transformed using square root transformation (“x + 0.5) before analyses. Benefit- Cost ratio (B:C) was calculated using the existing market rates. The major weed flora observed in the experimental field was jungle rice (*Echinochloa colona* (L.) Link), Chinese sprangletop (*Leptochloa chinensis* (L.) Nees), east Indian globe thistle (*Sphaeranthus indicus* L.) and globe fringerush (*Fimbristylis miliacea* (L.) Vahl). Analyses of the relative density revealed that jungle rice was the major grassy weed infested the experimental field. Sequential application of pre- and post- emergence application of pendimethalin and bispyribac-sodium herbicides integrated with hand weeding resulted in lower weed dry weight (3.7 g/m^2), higher rice grain yield (3.86 t/ha) and weed control efficiency (97.8%). Economically, application of pre-emergence pendimethalin integrated with a manual weeding at 40 DAS had superior B:C ratio (1.6) to other weed interventional methods. Uncontrolled weeds resulted in 69.6% yield loss in direct seeded semi-dry rice in the coastal deltaic region of Karaikal, Puducherry U.T.

Weed management in direct-seeded rice

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A field experiment was carried out during *Kharif* 2015, 2016 and 2017 for three years at Agricultural Research Station, Vadgaon Maval, Pune, Maharashtra. The experiment consisted of nine treatments comprising of unweeded check, weed free and weed control methods *viz.* pre-emergence application of pendimethalin 30% EC (1.0 kg/ha, 2-3 DAS) *fb* post-emergence application of metsulfuron-methyl 10% + chlorimuron-ethyl 10% WP (0.004 kg/ha, 25 DAS), pre-emergence application of pretilachlor 30.7% EC (0.450 kg/ha, 2-3 DAS) *fb* post emergence application of metsulfuron-methyl 10% + chlorimuron ethyl 10% WP (0.004 kg/ha, 25 DAS), pre-emergence application of oxyflourfen 23.5% EC (0.150 kg/ha, 2-3 DAS) *fb* post emergence application of metsulfuron-methyl 10% + chlorimuron- ethyl 10% WP (0.004 kg/ha, 25 DAS), pre-emergence application of pendimethalin 30% EC (1.0 kg/ha, 2-3 DAS) *fb* post-emergence application of azimsulfuron 50% DF (0.035 kg/ha, 25 DAS), pre-emergence application of pretilachlor 30.7% EC (0.450 kg/ha, 2-3 DAS) *fb* post-emergence application of azimsulfuron 50% DF (0.035 kg/ha, 25 DAS), pre-emergence application of oxyflourfen 23.5% EC (0.150 kg/ha, 2-3 DAS) *fb* post-emergence application of azimsulfuron 50% DF (0.035 kg/ha, 25 DAS), Hand weeding (25 and 45 DAS). The experiment was laid out in randomized block design with three replications. The rice variety 'Phule Samruddhi' was sown at 22.5 cm distance during *Kharif* 2015, 2016 and 2017. All the herbicides were sprayed by using water 500 L/ha with the help of sprayer fitted with flat fan nozzle. The weed samples taken out as per treatment were oven dried for about one week and dry weight was recorded. All the other recommended package of practices except weed control was followed to raise the direct dry seeded crop. In the experimental plots, dominant weed flora consisted of monocots as *Echinochloa colona* and *Cynodon dactylon* among grasses; *Cyperus iria* and *Cyperus difformis* among sedges while dicots like *Eclipta alba*, *Portulaca oleracea, Celosia argentea* and *Ludwigia parviflora* for three years. From the pooled data it was observed that the pre-emergence application of pretilachlor 30.7% EC 0.450 kg/ha at 2-3 days after sowing followed by post-emergence application of azimsulfuron 50% DF 0.035 kg/ha at 25 days after sowing as weed control measure in direct seeded rice having lowest weight of dry matter of weed (19.50 g/m^2) with higher weed control efficiency (87.67%)and lower weed index (2.78) with the highest net returns (` 82777/ha) and with higher B-C ratio (2.8). The gram was dibbled immediately after harvest of experimental paddy plots to observe the effect of different treatments on succeeding crop. The various herbicides applied to the paddy crop did not affect the germination of the succeeding crop of gram. On the basis of this study, in drilled paddy for effective management of weeds and higher economical returns the pre-emergence application of pretilachlor 30.7% EC, 0.450 kg/ha at 2-3 days after sowing followed by post-emergence application of azimsulfuron 50% DF, 0.035 kg/ha at 25 days after sowing in 500 liters of water is recommended.

Weed dynamics in dry-seeded rice as influenced by planting methods and water management

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Rice (*Oryza sativa* L.) is a staple food crop of India cultivated in the area of 43.39 Mha with a production of 104.32 Mt and average productivity of 2.40 t/ha during 2015-16 (Directorate of Economics and Statistics, 2016). Declining water table, increasing costs of production and climatic changes have a major problem in irrigated rice system. As standing water itself work as the herbicide in rice field but when it drained out and kept the soil saturated to aerobic condition, the weeds become a major concern in dry-seeded rice. Hence, under the aerobic condition, it is necessary to evaluate different pre- and post-emergence herbicides that are formulated from time to time to provide wider options for weed control in rice. Therefore the present study was undertaken to study the interaction effect of planting methods, water management and weed management in dry-seeded rice.

The experiment was conducted in the Irrigation Plots (UGC, SAP project), Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (Uttar Pradesh) during the *Kharif* seasons of 2016 and 2017. The experiment was laid out in the split-plot design replicated four times. The main plot comprises (2 planting method) *viz.* Conventional method (flatbed), Farrow irrigated raised bed system (FIRB), and water management practices *viz.* alternate wetting and drying (AWD) and saturation to field capacity in weed management practices *viz.* weedy check, two hand weeding at 20 and 40 DAS, pendimethalin 1 kg/ha (PE) *fb* bispyribac sodium 25 g/ha at 4-6 leaf stage of weeds, oxadiargyl 90 g/ha (PE) *fb* penoxsulam 22.5 g/ha at 4-6 leaf stage of weeds, flufenacet 120 g/ha (PE) *fb* pyrazosulfuron 20 g/ha+ bispyribac sodium 25 g/ha at 4-6 leaf stage of weeds were allocated in subplots during both the year of examination.

The plots of dry-seeded rice crop was infested with prominent grasses *viz. Echinochloa colona, E. crus-galli* and *Cynodon declylon*, major sadges *viz. Cyperus rotundus, Cyperus iria* and *Fimbristylis miliacea* and by dominant BLW *Caesulia axillaris, Eclipta alba, Amannia baccifera, Caesulia axillaris* and *Phylanthus niruri*. The significantly lowest weed density was found in the combination of furrow irrigated raised bed system (FIRB) with pre-emergence application of flufenacet 120 g/ha *fb* pyrazosulfuron 20 g/ha + bispyribac sodium 25 g/ha at 4-6 leaf stage of weeds at 40 DAS. Similarly, the significant interaction of water management and weed management was found and the lowest weed density was reported in treatment combination of alternate wetting and drying with combination to pre-emergence application of flufenacet 120 g/ha *fb* pyrazosulfuron 20 g/ha + bispyribac sodium 25 g/ha at 4-6 leaf stage of weeds. The maximum weed control efficiency was reported in furrow irrigated system in planting method and alternate wetting and drying over saturation. Among the herbicide treatment, the lowest weed density was reported in flufenacet 120 g/ha *fb* pyrazosulfuron 20 g/ha + bispyribac sodium 25 g/ha at 4-6 leaf stage of weeds at 40 DAS.

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Effect of pre- and post-emergence herbicides on the soil microflora of dry direct-seeded rice

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The use of herbicides in dry direct-seeded rice may affect the biological activity of the soil and thus influence the soil nutrient status, health and productivity. Hence, a field experiment was conducted at Main Research Station, Hebbal, Bengaluru during *Kharif* 2016 and 2017 to study the effect of different herbicide combinations and weed management practices on major soil microflora in dry direct-seeded rice. The experiment consisted 12 treatments, *viz.* bensulfuron-methyl + pretilachlor *fb* triafamone + ethoxysulfurn (RM) (60 + 600/60 g/ha), oxadiargyl *fb* triafamone + ethoxysulfuron (RM) (100/60 g/ha), pendimetalin *fb* triafamone + ethoxysulfuron (RM) (1000/60 g/ha), pyrazosulfuron-ethyl *fb* triafamone + ethoxysulfuron (RM) (20/60 g/ha), bensulfuron-methyl + pretilachlor *fb* bispyribac sodium (60 + 600/25 g/ha), oxadiargyl *fb* bispyribac sodium (100/25 g/ha), pendimethalin* *fb* bispyribac sodium (1000/25 g/ha), pyrazosulfuron-ethyl *fb* bispyribac sodium (20/25 g/ha), pendimethalin* *fb* penoxsulam + cyhalofop-butyl (RM) (1000/135 g/ha), three mechanical weedings (20, 40, 60 DAS), hand weedings (20, 40, 60 DAS) and weedy check were tested in a Randomized Block Design with three replications. The soil type was sandy loam with a pH of 6.8, with organic carbon of 0.55%, initial soil bacteria (33.65 x 10^5 CFU/g of soil), fungi (21.86 x 10^4 CFU/g of soil), actinomycetes (18.17 x 10^4 CFU/g of soil) population, urease (18.14 µg NH_4-N/g soil/hr) and dehydrogenase (104.45 µg TPF g/soil 24/hr) activity. Among the different herbicide combinations, pre-emergence application of bensulfuron-methyl + pretilachlor *fb* bispyribac sodium recorded significantly highest grain, straw yield and also effective weed control was noticed. These treatment combination recorded bacteria (33.63 x 10^5 CFU/g of soil), fungi (21.83 x 10^4 CFU/g of soil), actinomycetes (18.46 x 10^4 CFU/g of soil) population and also on soil enzymes like urease (18.33 µg NH_4-N/g soil/hr) and dehydrogenase (106.07 µg TPF g/soil 24/hr) activity. These herbicide are found to be effective in controlling weeds along with least effect to soil biological activity at 60 DAS. Whereas, significantly lowest population of bacteria (26.60 x 10^5CFU g^{-1} soil), fungi (17.27 x 10^4 CFU g^{-1} soil), actinomycetes (14.60 x 10^4 CFU g^{-1} soil) and also on soil enzymes like urease (14.50 µg NH_4-N g^{-1} soil hr^{-1}) and dehydrogenase (83.92 µg TPF g^{-1} soil 24 hr^{-1}) activity was noticed in pre-emergence application of pendimethalin *fb* penoxsulam + cyhalofop-butyl as post-emergence. The study revealed that pre-emergence application of bensulfuron-methyl + pretilachlor *fb* bispyribac sodium found to be the best herbicide combination for better control of weeds, higher productivity along with least effect on soil microflora in dry direct-seeded rice.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Effect of green manuring, nitrogen and herbicides on weeds and productivity of dry-seeded rice

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Rice is the leading cereal crop of the world and staple food for more than half of the world population. In India, it is a dominating staple food crop of fertile and alluvial soils of North West India and occupies an area of 43.9 million ha with a total production of 109.7 million tonnes. In Asia, rice is commonly grown by transplanting into puddled soil. Repeated puddling, however, adversely affects the soil physical properties by destroying soil aggregates, reducing permeability in the subsurface layers, and forming hardpans at shallow depths. Moreover, puddling and transplanting require large amounts of water and labour, both of which are becoming increasingly scarce and expensive, making rice production less profitable. Dry direct seeding of rice in unpuddled soil seems potential resource conservation strategy for achieving high water productivity and eliminating the time and edaphic conflicts in rice-wheat cropping system of Punjab. Weed flora composition can change drastically with a shift from puddle transplanted rice to some form of alternative tillage and rice establishment methods. These weeds severely disturb the growth of rice and sometimes result in crop failure. Also, the weed flora emerges in several flushes during the crop growth period. Therefore, integrated use of different weed management techniques in suitable and compatible manner for effective weed control should be followed in dry-seeded rice.

The effects of green manuring, nitrogen and herbicides on weed seed bank and dynamics; and productivity of dry seeded rice were investigates in a field trial conducted in 2017 at Ludhaina, India. Two green manure treatments (without and with green manure of sunnhemp (*Crotalaria juncea*) at 50 kg seed/ha) and three nitrogen levels (120, 150 and 180 N kg/ha) were kept in main plots whereas three weed control treatments weedy check, pendimethalin plus pyrazosulfuron as pre-emergence followed by *fb* bispyribac sodium as post-emergence herbicide and integrated weed management (pre- *fb* post-emergence herbicides plus one hand weeding) were kept in sub plots in a split plot design with three replications.

Major weed flora in the experimental field included *Echinochloa colona*, *E.crus-galli*, *Dactyloctenum aegyptium*, *Digitaria sanguinalis*, *Cyperus rotundus* and *Digera arvensis*. Green manuring with sunnhemp favored density, biomass and seed bank of *E. colona* and *D. aegyptium* and gave significantly lower rice grain yield than without green manuring. At higher nitrogen levels, dry-seeded rice gave more promising results in terms of yield under higher weed pressure. Among weed control, integrated weed management treatment gave significantly higher rice grain yield and control of diverse weed flora of grass and sedges than herbicides alone; application of pre- *fb* post-emergence herbicides gave significantly higher grain yield than weedy check. The combination of 180 kg N/ha, integrated weed control and no green manure gave the highest rice grain yield.

Weed management strategy in direct-seeded rice in north eastern region of India- A critical review

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Being the seventh biodiversity hotspot of world, north eastern region of India is blessed by God where “rice” is the most consumed cereal grain. Although the major production of rice is based on transplanting system, still then due to increasing water scarcity, uncertainty of monsoon and increasing labour wages the popularity of direct-seeded rice is enhancing in this region day by day. Having many benefits over transplanted rice like at par yield, less water utilization, less labour cost, higher gross return, reduced methane emission and sustainable environmental safety, direct seeded rice is facing a big challenge like weed control. Failure in control of weeds in direct seeded rice may lead to yield loss up to an extent of 50-90%. The critical weed control period remains from 15 DAS to 45 DAS in case of direct seeded rice. The major weeds found in this region in direct seeded sytem, such as *Echinochloa crusgalli* and *E. colona* as grasses; *Cyperus iria* and *Cyperus esculentus* as sedges; *Commelina benghalensis, Ludwigia parviflora* and *Eclipta alba* as broad-leaf weed; *Monochoria vaginalis and Marsilia quadrifolia* as submerged weeds force less rice productivity. As the nature of weeds are dynamic and a shift in their abundance and dominance in direct seeded rice is a major issue in front of the researchers. It was reported that thrice cross ploughing in wet-direct seeded rice is the best method to control the weeds. That cross ploughing locally called as “beushening” which is done with the help of narrow country plough. Application of pretilachlor 0.75 kg/ha + safener + one hand weeding at 30 DAS and butachlor 1.5 kg/ha + one hand weeding results better results. In upland direct seeded rice pre-emergence application of oxyflurofen 300 g/ha + 2, 4-D 0.5 kg/ha as post-emergence herbicide may be supplemented for weed control. Application of 10% NaCl at 20 DAS and 40 DAS found to be another alternative for such purpose. Again higher yield and more profit from zero-till direct-seeded rice were obtained with the application of bispyribac-sodium + azimsulfuron herbicides as a tank mixture. Results of different herbicidal treatment reveals about resistance of herbicide due to prolonged application. Similarly it was found that sole measure shows less weed control efficiency. Hence, for effective, long-term and sustainable weed control in direct-seeded rice systems, there is a requirement of integrated weed management strategy which should include preventive measures, cultural control measures, mechanical control measures, chemical control measures and biological control measures. Keeping major advantage over transplanted rice for enhancing rice production, the direct seeded rice process has to be adapted with holistic and integrated weed management strategy.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Bio-efficacy studies of butachlor in transplanted rice

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Rice is one of the most important cereal crops in India. It meets demand of staple food for two third population of the country. 12 - 98% yield loss occurred in rice due to weed infestation depending upon type and method of rice establishment. A field experiment had been conducted to assess the bio-efficacy of butachlor 50% EC against weed flora in transplanted rice during *Kharif* season of 2015 at the Instructional Farm (22^{0}56^{Œ§} N, 88^{0}32^{Œ§} E and 9.5 m above MSL), Jaguli, BCKV, Nadia, West Bengal in medium fertile sandy loam soil with a normal pH (6.9) and medium water holding capacity. The experiment was laid out in randomized block design (RBD) with nine weed management treatments along with weedy check with three replications. Variety *'IET 4786'* (Satabdi) was used for this experiment. Treatments included six doses of butachlor 50% EC (1.00, 1.25, 1.50, 1.75, 2.00 and 2.25 kg/ha), pendimethalin 30% EC 1.25 kg/ha, pretilachlor 37% EW 0.65 kg/ha and hand Weeding along with weedy check. All the doses of butachlor, pendimethalin and pretilachlor were applied at 2 days after transplanting (DAT) and hand weeding was done in two times at 20 DAT and 40 DAT.

The experimental field was infested by different grassy, broad-leaf and sedge weeds. Among grasses- *Echinochloa colona, Echinochloa formosensis,* and *Leersia hexandra*; among sedges - *Cyperus iria* and *Cyperus difformis and* among broad-leaf weeds - *Marsilea quadrifolia, Alternanthera philoxeroides, Eclipta alba, Ludwigia parviflora, Ammania baccifera* and *Monochoria vaginalis* were found. Twice hand weeding exhibited as the best weed management practice, however, among the herbicidal treatments, butachlor 2.25 kg/ha recorded excellent control of all categories of weed which was at par with butachlor 2.00 kg/ha butachlor 1.75 kg/ha and 1.5 kg/ha also showed effective reduction in weed density. Highest weed control efficiency (90.80% and 87.10% at 45 and 75 DAT respectively) were noted down by twice hand weeding which was at par with butachlor 2.25 kg/ha and butachlor 2.00 kg/ha.

Grain yield data revealed that all the weed management treatments noted significantly higher grain yield than the weedy check. Twice hand weeding treatment recorded the highest grain yield (4.95 t/ha). However, among herbicidal treatments, butachlor 2.25 kg/ha and 2.00 kg/ha were found to be at par with each other and with hand weeding treatment. From the experimental data it can be concluded that butachlor 2.00 kg/ha can be used for cost effective management of weed flora under transplanted rice cultivation system in new alluvial zone of West Bengal.

Weed management in transplanted rice with special reference to *Commelina benghalensis* L. in Katni district of Madhya Pradesh

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Rice (*Oryza sativa* L.) is the most widely cultivated rainy season's cereal crop in Madhya Pradesh. However, its production is constrained by major biotic constraints namely weed. Weeds are potential yield reducers that are economically more harmful than insects, fungi or other crop pests in many situations. Weeds compete with crop and reduce the quality as well as quantity of the produce. Therefore, timely weed management is crucial for attaining maximum yield of rice crop. According to recent study, weeds caused 21.4% and 13.8% yield losses in direct-seeded rice and transplanted rice, respectively (Gharde *et al.* 2018). Owing to favourable weather and soil moisture regimes, *Commelina* spp. (L.) infestation is a major biotic constraint to rainy rice production in Kymore Plateau Satpura Hills of Katni district of Madhya Pradesh. Season-long infestation of this weed alone causes grain yield reduction by 13-40% and removes considerable amount of soil nutrients (Shukla *et al.* 2014). Keeping, this in view, a replicated on-farm trial was conducted in five villages (similar agroclimatic conditions) namely Deori (23^{0}89'N 80^{0}29'E), Umariyapan (23^{0}50'N 80^{0}27'E), Banda (23^{0}68'N 80^{0}34'E), Lakhapateri (23^{0}69'N 80^{0}32'E) and Dhundhari (23^{0}73'N 80^{0}30'E) of Katni district of Madhya Pradesh to validate, refine and popularize the technology for managing *Commelina benghalensis* L. in transplanted rice during 2014–17. The aim of the study was to find out the effectiveness of bispyribac sodium 20 g/ha, pyrazosulfuron 20 g/ha and pendimethalin 1.5 kg/ha over farmers practice of hand weeding twice at 30 and 60 DAT and unweeded control on the management of weeds and profitability of rice production. In farmers' practice (hand weeding twice at 30 and 60 DAT), weeds particularly *C. benghalensis* were not controlled due to its deep-tap root system and faster regrowth soon after weeding as well as cutting also having capacity to regenerate. On the other hand, application of bispyribac sodium being at par with pyrazosulfuron and pendimethalin significantly reduced weed density upto 3.48 no./m^2 and dry weight upto 3.57 g/m^2 of total weeds compared to other treatments and resulted in the highest weed control efficiency (93.8%). Higher values of yield attributes such as number of panicles (229/m^2) grain yield (3.46 t/ha) and net returns (` 31820) were also recorded with bispyribac sodium 20 g/ha compared to other treatments. However, rice grain yield was not significantly affected within herbicide treatments. It also resulted in 12.5% higher grain yield over farmers practice. This also recorded significantly the lowest N, P and K uptake by weeds (5.8 kg N, 1.1 kg P and 6.9 kg/ha) over other treatments due to efficient control of weeds.

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Efficacy of broad spectrum herbicides and their combinations on yield and economics of direct-sown rice

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Rice is the principal food crop of the country and the country became self-sufficient in rice due to increase in area under summer rice in eastern part of the country. It is commonly grown by transplanting of seedlings in puddled soil (TPR). The more labour requirement and high cost of labour rendered the production system less profitable. Wet direct seeding is a viable alternate to TPR and sowing of pre-germinated seeds by using drum seeder offers benefits like reduction in labour requirement due to elimination of nursery preparation and makes rice cultivation more profitable. Weeds are considered as major biotic stress and caused yield reduction to the extent of 65% in drum seeded rice. Manual weeding is tedious, costly and not at all cost-effective. Though several herbicides are proved effective but the environmental consequences advocated the use of low dose broad spectrum herbicides and their mixtures to provide weed control in direct seeded rice for higher productivity and profit. Therefore, the study was undertaken to evaluate the efficacy of different broad spectrum herbicides and their combinations on the performance of direct-sown rice established by drum seeder.

Field experiment was carried out during dry season of 2015 and 2016 at Gerua, Assam. The experiment was conducted in RCBD and 10 treatments *viz.*, azimsulfuron (35 g/ha) at 20 days after sowing (DAS), flucetosulfuron (25 g/ha) at 20 DAS, bispyribac sodium (30 g/ha) at 20 DAS, bensulfuron-methyl + pretilachlor at (60 + 600 g/ha) at 10 DAS, azimsulfuron + bispyribac sodium (22 + 25 g/ha) at 20 DAS, flucetosulfuron (25 g/ha) at 5 DAS *fb* bispyribac sodium (25 g/ha) at 20 DAS, manual weeding twice at 20 and 40 DAS, mechanical weeding by paddy weeder at 20 DAS *fb* manual weeding at 40 DAS, weed free and weedy check. Pre-germinated seeds of the rice variety ‘Naveen’ were sown by using 12 row drum seeder at 20 x 10 cm on puddled saturated soil. The crop was raised with standard package of practices and harvested at maturity. Biometrical observations on weed and crop were recorded at different growth stages following the standard procedure.

The experimental results revealed that there was 14 weed species comprising of 8 families appeared in crop fields. Among the different categories of weeds, sedges were dominant (71.5%) followed by grasses (15.1%) and broad-leaved weeds (13.4%). The yield loss due to crop-weed competition under weedy check was 37.4%. Herbicidal treatments azimsulfuron + bispyribac sodium (22 + 25 g/ha), flucetosulfuron at (25 g/ha), bispyribac sodium (30 g/ha) and bensulfuron-methyl + pretilachlor (60 + 600 g/ha) registered 50.6, 48.5, 47.9 and 47.7% increase in grain yield over the weedy check, respectively and comparable with hand weeding twice. Among the herbicides, bensulfuron-methyl + pretilachlor (60 + 600 g/ha) applied at 10 DAS and flucetosulfuron (25 g/ha) at 20 DAS recorded significantly higher B: C ratio over hand weeding twice.

From the study it may be concluded that bensulfuron-methyl + pretilachlor (60 + 600 g/ha) and flucetosulfuron (25 g/ha) were controlling the weeds effectively and could be recommended for broad spectrum weed control with higher profit under direct-sown rice established mechanically by drum seeder.

Weed management in rice based cropping systems in India

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Weed competition is a major constraint in all the rice production systems in India. Weeds are identified as a major biological constraint that hinders attainment of optimal rice productivity in major rice producing countries of South Asia like India (Rao *et al.* 2015a; Rao and Nagamani 2010). In addition to the costs of weed control, weeds account for yield loss in agricultural production due to weeds amounts to INR 1050 billion per annum (NRCWS 2007; Varshney and Prasad Babu 2008) in India. Rice yield losses due to uncontrolled weed growth and weed competition were least (12%) in transplanted rice (Singh *et al.* 2011) and losses were the highest in aerobic direct- seeded rice on a furrow-irrigated raised bed systems (Singh *et al.* 2008) and in dry-seeded rice sown without tillage (Singh *et al.* 2011). The rice grain yields were comparable across all establishment methods of rice when weeds were managed (Singh *et al.* 2008). Thus, weed management is the major prerequisite for improved rice productivity and production using different methods of rice establishment (Rao *et al.* 2007).

Important weeds in upland rice include the perennial species *Cyperus rotundus* and *Imperata cylindrica*, the annual species *Euphorbia heterophylla*, *Digitaria horizontalis*, and the parasitic weeds *Striga* spp. In lowland rice the perennial weeds: *Cyperus rotundus*, *C. esculentus* and *Oryza longistaminata* and annual weeds *Echinochloa* spp., *Cyperus difformis*, *C. iria*, *Fimbristylis littoralis*, *Ischaemum rugosum*, and *O. barthii* cause serious losses.

Weeds flora was reported to vary with location, method of rice establishment, cultural practices used and associated environment. Common weed management practices in rice based cropping systems include soil tillage, hand or hoe weeding, herbicides, flooding, fallow and crop rotations, and these are often used in combination. Labor shortages and lack of access to information, inputs, and credits are widespread constraints for farmers. The use of herbicide tolerant rice can help improve control of weeds, including weedy rice, and reduce weed control costs and the labor associated with manual removal of weeds. To optimize financial, social and environmental costs and benefits, integrated and ecological management approaches are advocated. Locally adapted and affordable combinations of preventive measures and interventions should be targeted.

Future weed research should aim to deliver the information and tools for the implementation of these approaches. This requires the generation of knowledge on weed biology and ecology and on the consequences of changes in management and the environment on weed populations. To address the diversity of rice based cropping systems in India, priorities need to be set and products and information delivered that take full account of local conditions. This will require farmer participatory approaches that are inclusive with respect to resource poor farmers and gender.

Bio-efficacy of post-emergence herbicides in direct-seeded rice

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A field experiment was conducted at Agricultural Research Farm of Institute of Agricultural Sciences, Banaras Hindu University, Varanasi; Uttar Pradesh to study the efficacy of post emergence herbicides in direct seeded rice. The onset of monsoon in this region normally takes place during the third week of June and ceases by the end of September or sometimes up to first week of October. The soil of experimental site was sandy clay loam in texture, low in organic matter (0.43%), low in available nitrogen (202.7 kg/ha), medium in available phosphorus (18.0 kg/ha) and potassium (209.2 kg/ha) and slighty alkaline in reaction (pH 7.2).Treatment consisted of two hand weeding, weedy, bispyribac Na 25 g/ha, bispyribac Na 25 g/ha + pyrazosulfuron 20 g/ha, bispyribac Na 25 g/ha + cono weeding, penoxsulam 1.02% (w/w) + cyhalofop-butyl 5.1% (w/w) 135 g/ha, penoxsulam 1.02% (w/w) + cyhalofop-butyl 5.1% (w/w) 150 g/ha, penoxsulam 1.02% (w/w) + cyhalofop-butyl 5.1% (w/w) 180 g/ha. All the herbicides were applied at 15-20 DAS as per treatment. In experimental field, dominant weeds were *Echinochloa colona* (53%), *Cynodon dactylon* (15%), *Cyperus rotundus* (18%) and other weeds like *Cyperus difformis* L., *Cyperus iria, Caesulia axillaris and Ammania baccifera* (14%). Results indicated that, application of penoxsulam 1.02% (w/w) + cyhalofop-butyl 5.1% (w/w) 180 g/ha provided the most effective weed control followed by two hand weeding under direct seeded condition than rest of the other treatments. This treatment control 76.47% of weeds as compared to weedy plots followed by two hand weeding (70.58%), penoxsulam 1.02% (w/w) + cyhalofop-butyl 5.1% (w/w) 150 g/ha (67.65%) and bispyribac Na 25 g/ha + pyrazosulfuron 20 g/ha (64.70%). At lower dose (135 g/ha) penoxsulam 1.02% (w/w) + cyhalofop-butyl 5.1% (w/w) was not very effective to control the weeds, it controls only 41.18% of weeds as compared to weedy.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Crop growth and weed dynamics in rice as influenced by irrigation and establishment methods

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The field experiment was conducted at Zonal Agricultural Research Station, Mandya under Cauvery command area of Karnataka to study the effect of irrigation, weed management practices and rice establishment methods on weed dynamics and growth of paddy during *Kharif* 2018. The experiment was laid out in a split plot design comprised of three main plot irrigation treatments, *viz*. continuous flooding, maintenance of saturation up to panicle initiation (PI) and flooding after PI and alternate wetting and drying (AWD) and five rice establishment methods, *viz*. drum seeding, broadcasting of sprouted rice, semi-dry rice, mechanical transplanting and manual transplanting in sub-plot. The combination of 15 treatments was replicated thrice and the paddy variety used was *'MTU 1001'*. The weed management was done through application of pre-emergence herbicides such as pendimethalin at 750 g/ha in semi-dry rice and bensulfuron methyl 0.6% + pretilachlor 6% GR at 10 kg/ha in other rice establishment methods. The major weed flora observed in the experimental site were *Fimbristylis miliacea*, *Cyperus difformis*, *Cyperus rotundus* (among sedges), *Echinochloa colona, Eleusine indica*, *Panicum repens*, *Commelina diffusa*, *Panicum tripheron* (among grasses) and *Spilanthes acmella, Mimosa invisa, Portulaca oleraceae, Ludwigia parviflora* and *Eclipta alba* (among broad-leaved weeds). The results revealed that maintaining continuous flooding recorded significantly lower total weed density (28.68 no./m^2) as compared to maintaining AWD (47.32 no./m^2) and maintaining saturation (46.4 no./m^2) at 30 DAS. Manual transplanting recorded lower total weed density (11.12 no./m^2) *fb* mechanical transplanting (10 no./m^2) and were significantly lower as compared to rest of the methods (51.32 to 79.76 no./m^2). At 60 DAS, no significant differences was observed (20.92 to 27.32 no./m^2) among irrigation methods while trend for crop establishment methods was same at 60 DAS. Further, broad-leaved weed density was influenced by irrigation methods while both broad-leaved and grass weed densities by rice establishment methods. The crop growth at 30 and 60 DAS were found statistically at par. Although, plant height was significantly higher in broadcasted rice as compared to rest of the establishment methods at 30 DAS. While at 60 DAS, semi-dry rice recorded higher plant height (43.07 cm) *fb* drum seeded rice (42.95 cm) and manual transplanted rice (42.85 cm) and was significantly higher than the rest of the methods (38.59 to 39.40 cm). The higher number of tillers was reported in semi-dry rice (47.98 and 153.29 no./m row length) and was significantly more as compared to rest of the rice establishment methods (12.51 to 29.13 and 57.02 to 109.98 no./m row length) at 30 and 60 DAS, respectively.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Crop growth and weed dynamics in rice as influenced by nutrient management under different establishment methods

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The field experiment was conducted during *Kharif* 2018 at Zonal Agricultural Research Station, V. C. Farm, Mandya under Cauvery Command area of Karnataka to study weed dynamics and growth of paddy as affected by nutrient management and rice establishment methods. The experiment was laid out in a split plot design comprised of three rice establishment methods, *viz*. semi-dry, drum-seeding and transplanting in main plots with five nutrient management levels, *viz*. 100% recommended dose (120:60:40 kg N: P_2O_5: K_2O/ha) of inorganic fertilizers (RDIF), 75% RDIF + 25% N equivalent organic nutrient (FYM), 150% RDIF, leaf colour chart (LCC) based nitrogen application and NPK as per UAS (B) package of practice (100:50:50 kg N: P_2O_5: K_2O/ha) in sub-plot. The combination of 15 treatments replicated thrice and the paddy variety used was *'MTU 1001'*. The weed management was done through application of pre-emergence herbicides such as pendimethalin (30% EC) at 3.33 litre/ha in semi-dry rice and bensulfuron methyl 0.6% + pretilachlor 6% GR at 10 kg/ha in other rice establishment methods. The common date of sowing either in main field or in nursery was taken for different rice establishment methods. The major weed flora observed in the experimental site were *Echinochloa colona*, *Echinochloa crus-galli* and *Panicum repens* among grasses; *Spilanthes acmella*, *Mimosa invisa*, *Ludwigia parviflora* and *Eclipta alba* among broad-leaved weeds and *Cyperus difformis* and *Cyperus rotundus* among sedges. The results revealed that transplanting recorded significantly lower total weed density (14 weeds/m^2) as compared to other rice establishment methods (35 to 39 weeds/m^2) at 60 DAS. Significantly lower total weed density was recorded in 150% RDIF (24 weeds/m^2) as compared to LCC based nitrogen application (34 weeds/m^2), but was statistically at par with rest of nutrient managements (28 to 31 weeds/m^2). The transplanting method of rice establishment with 100% RDIF recorded significantly lower weed density than rest of treatments. The broad-leaved weed was influenced by semi-dry rice and grass weed density by drum seeding rice establishment method in the experiment. The plant height and number of tillers per meter row length of paddy was not significantly influenced by rice establishment methods. However, 150% RDIF recorded taller plants and more tillers followed by 100% RDIF as per UAS (B) package but was significantly superior over rest of nutrient managements at 60 DAS.

Weed and water management of aerobic rice in Kerala

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Aerobic rice technology is a promising way aimed at growing rice like any other upland crop. It entails the growing of rice in aerobic soils, with the use of external inputs such as supplementary irrigation and fertilizers and aiming at high yields. Weeds are the major menace that restricts the yield potential of aerobic rice. With changing global climate and unstable hydrological cycles, different water saving techniques have to be evaluated especially in rice. A study was under taken at Agronomic Research station, Chalakkudy of KAU during 2016-2017 to assess the response of weeds to varying levels of irrigation and herbicides under aerobic condition. The trial was laid out in a split plot with three levels of irrigation in the main plot (Irrigation at 10, 20 and 30 mm Cumulative Pan Evaporation (CPE)) and five weeed management treatments in the sub plot (pre-emergent herbicide oxadiargyl *fb* hand weeding, 2, 4-D sodium salt, and bispyribac sodium at 20 days after sowing (DAS), hand weeding at 20 and 40 DAS and unweeded control). Irrigation at 30 mm CPE favoured the growth of maximum weeds and recorded the highest weed dry matter and density. The response of weeds were different with different levels of irrigation. Grass, sedges and broad-leaved weeds responded differently to different irrigation levels with sedges dominating only in frequently irrigated treatments. Grass and broad-leaved weeds density under 20 and 30 mm CPE resembled upland conditions, suggesting the importance of maintaining a near to field capacity moisture level in the filed throughout the crop growth for controlling the weeds. Irrigation at 10 mm CPE effectively controlled more weeds and recorded the lowest weed density. At 90 DAS, 10 mm CPE recorded 20% higher weed control efficiency than 30 mm CPE. Among weed management treatments hand weeding twice at 20 and 40 DAS recorded the highest weed control efficiency. This proved that the period of crop weed competition is longer for aerobic rice and weed management up to 40 DAS resulted in better growth and yield. This was *fb* the application of oxadiargyl and bispyribac sodium. Oxadiargyl was successful enough to control the weeds as a pre-emergent herbicide. 2, 4-D effectively controlled broad-leaved weeds but grass weeds showed over dominance in 2, 4-D applied treatments. Bispyribac sodium was effective in controlling all types of weeds, indicating the importance of a broad spectrum herbicide in aerobic rice. A combination of higher irrigation frequency (Irrigation at 10 mm CPE) and late hand weeding resulted in better control of weeds and there by grain yield of aerobic rice. Combination of Irrigation at 10 mm CPE and oxadiargyl *fb* bispyribac sodium was found economically more viable than other treatments.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Efficacy of pyribenzoxim against weeds in direct-seeded rice under Kymore plateau and Satpura hills

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A field experiment entitled "Evaluation of post emergence applications of pyribenzoxim against weeds in direct seeded rice" was conducted during *Kharif* season of 2017. The eight treatments comprising of four doses of pyribenzoxim at 25, 30, 35 and 60 g/ha, alone application of fenoxaprop-p-ethyl 56.95 g/ ha and oxadiargyl 100 g/ha as post-emergence, hand weeding twice at 15 and 35 DAS including weedy check, were laid out in randomized complete block design with 3 replications.

Digitaria senguinalis (21.86%) was rampant closely followed by *Physalis minima* (21.38%). However, other weeds like *Cyperus rotundus, Echinochloa colona* and *Alternanthera sessilis* were also present in less numbers with rice in weedy check plots. The control plots receiving no weed control treatment had maximum weed density and dry weight. Application of pyribenzoxim caused appreciable reduction in density and dry weight. However the activity of pyribenzoxim was further increased with increase of herbicide dose. Application of pyribenzoxim at 30 g/ha was found suitable for effective control of weeds resulted in higher weed control efficiency of *Digitaria senguinalis, Echinochloa colona, Cyperus irria, Physalis minima,* and *Alternanthera sessilis* to the tune of 73.25%, 78.27%, 78.45%, 76.00%, and 77.72% respectively followed by pyribenzoxim at 35 g/ha in direct seeded rice. Growth parameters (*viz.* effective tillers per meter and LAI), yield attributes (*viz.* effective tillers per meter, panicle length, total and sound grains per panicle) were significantly more with the application of pyribenzoxim at 30 g/ha as compared to rest of the doses. The lowest grain yield was recorded when weed control was not done in rice in weedy check plots, but it was increased identically when weed control measures were adopted. Among herbicidal treatments, The highest grain yield was recorded with application of pyribenzoxim at 35 g/ha which was statistically at par with pyribenzoxim at 30 g/ha. As regards the economics less expenditure was incurred under herbicidal treatments as compared to hand weeding twice. Application of pyribenzoxim at 30 g/ha found more remunerative followed by pyribenzoxim at 35 g/ha as both received higher values of NMR (` 11084 and ` 10604 per ha and B:C ratio (1.38 and 1.36) respectively as compared to other herbicidal treatments.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Weedy rice management in transplanted rice

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Rice occupies an important position as food crop in Jammu and Kashmir. It is the staple food of the Kashmir region and the second most important food crop of Jammu region after wheat. In Jammu & Kashmir rice occupy an area of 304.05 thousand ha with production of 6466 thousand quintals and average productivity of 2.13 t/ha. The rice production in Jammu region is major commercial activity, especially in irrigated subtropics. Various production constraints of rice in Jammu and Kashmir have been identified. Among them in recent years, the rice production especially in sub-tropical plains of Jammu division is encountering a new biotic threat 'Weedy Rice". Weedy rice has posed a tremendous threat to rice farming owing to its morphological similarity to rice plant and has a high competitive potential to threaten yield sustainability of rice-based production systems. As in whole of South Asia, the weedy rice has emerged as a new potential challenge to rice production in Jammu & Kashmir also. Some of the important characteristics of weedy rice which make it essentially one of the biggest threats to rice production are early shattering of the seeds and the longevity of weedy rice seeds which is generally longer & variable then that of cultivated rice. Multipronged strategies need to be integrated to discourage weedy rice infestations. In the famous rice belt of R.S. Pura area of Jammu district of Jammu and Kashmir State, weedy rice has been found to severely infest the transplanted basmati rice leading to heavy losses in crop yield. The population of weedy rice started to increase over the years through the increasing seed bank and in past few years its population has increased a lot in the farmer's fields which reduce the rice yield substantially. For weedy rice management in transplanted rice a two years field experiment was conducted (*Kharif* 2015 and 2016) at farmers' to identify the appropriate management options and one year OFTs were conducted to validate the best management practices. In R. S. Pura belt of Jammu division the five different strains of weedy rice were identify which are differ in morphology to each other. Weedy rice density as well as weedy rice biomass/m^2 was found to be lowest in the treatments involving stale seed-bed with herbicides (Glyphosate 1.5 kg/ha and Paraquat 0.8 kg/ha). Weedy rice density as well as weedy rice biomass/m^2 was statistically at par in recommended practice (Butachlor 1.5 kg/ha) and weedy check. All the weed management treatments recorded significantly higher grain yield of rice as compared to weedy check and recommended practice (Butachlor 1.5 kg/ha). The stale seed-bed technique along with subsequent use of glyphosate 1.5 kg/ha or paraquat 0.8 kg/ha prior to transplanting was found to be most effective in controlling weedy rice infestations in transplanted rice besides enhancing the crop productivity in the infested area of the Jammu region.

Weeds and weed management in rice based cropping system

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Rice based cropping system can be described as mix of farming practices that comprises of rice as the major crop followed by subsequent cultivation of other crops. Inter-cropping of rice and other compatible crops is also widely practiced in many regions. Rice based cropping system is a major cropping system practiced in India, which include the rotation of crops involving rice, pulses, oil seeds, cotton, sugarcane, green manures, vegetables, *etc*. Weeds are a major impediment to rice production through their ability to compete for resources and their impact on product quality. Weeds are responsible for heavy rice yield losses, to the extent of complete crop loss under extreme conditions. Out of the losses due to various biotic stresses, weeds are known to account for nearly one third. Weed competition would be less severe under transplanting than those under direct-seeding. Uncontrolled weeds reduced the grain yield. Yields were comparable across all establishment methods of rice when competition from weeds was removed. Thus, weed control is major prerequisit for improved rice productivity and production using different methods of rice establishment. Important weeds in upland rice include the perennial species *Cyperus rotundus, Imperata cylindrica* and *Chromolaena odorata*, the annual species *Euphorbia heterophylla*, *Digitaria horizontalis*, and the parasitic weeds *Striga* spp. In lowland rice, the perennial weeds: *Cyperus rotundus*, *C. esculentus* and *Oryza longistaminata* and annual weeds *Sphenoclea zeylanica*, *Echinochloa* spp., *Cyperus difformis, C. iria, Fimbristylis littoralis, Ischaemum rugosum*, and *O. barthii* cause serious losses. Common weed management practices in rice based cropping systems include soil tillage, clearance by fire, hand or hoe weeding, herbicides, flooding, fallow and crop rotations, and these are often used in combination. Weed management must aim at reducing the weed population to a level at which weeds occurrence has no effect on farmers economic and ecological interests. By using different appropriate management practices against weeds, farmers have more options for controlling weeds, thereby reducing the possibility of escapes and weed adaptation to any single weed management tactic. IWM is a science-based decision-making process that coordinates the use of environmental information, weed biology and ecology, and all available technologies to control weeds by the most economical means, while posing the least possible risk to people and the environment. Effective IWM combines preventive, cultural, mechanical and biological weed control methods in an effective, economical and ecological manner. Apply any one of the pre-emergence herbicides *viz*., pretilachlor + safener 0.3 kg/ha, on 3rd or 4th day after sowing to control weeds in the lowland nursery. Keep a thin film of water and allow it to disappear. Use of rotary weeder from 15 DAT at 10 days interval. It saves labour for weeding, aerates the soil and root zone, prolongs the root activity, and improves the grain filling though efficient translocation and ultimately the grain yield. Cultural practices like dual cropping of rice-azolla, and rice-green manure (described in wet seeded rice section 2.5 & 2.6 of this chapter) reduces the weed infestation to a greater extent. Summer ploughing and cultivation of irrigated dry crops during post-rainy periods reduces the weed infestation.

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Crop establishment and integrated weed management effects on weed dynamics, yield, economics and moisture use efficiency of direct-seeded rice

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Rice (*Oryza sativa* L.) is an important staple crop in India, where it is mainly grown by manual transplanting of seedlings into puddled soil. Recently, however, there is a trend toward dry-direct seeded rice (DSR) because of labour and water scarcity. In DSR, weeds are the main biological constraint. Herbicides are used to manage weeds in DSR systems, but the use of herbicides alone does not provide effective and sustainable weed control. Therefore, a field experiment was conducted during rainy season of 2008 and 2009 at the Agricultural Research Farm of Banaras Hindu University, Varanasi, Uttar Pradesh, India. There were 3 crop establishment methods, namely zero-till DSR, zero-till DSR with anchored residues and reduced tillage DSR in main plot and nine weed management treatments *viz.* weedy check, weed free, hand weeding (20 and 40 DAS), glyphosate 1000 g/ha (pre-seeding) *fb* pendimethalin 1000 g/ha (pre-em), *fb* 2,4-D EE 500 g/ha at 25 DAS, pendimethalin 1000 g/ha (pre-em) *fb* 2,4-D EE 500 g/ha at 25 DAS + one hand weeding (HW) at 40 DAS, pendimethalin 1000 g/ha (pre-em) *fb* metsulfuron+cholorimuron 4 g/ha at 20 DAS + one HW at 40 DAS, pendimethalin 1000 g/ha (pre-em) *fb* azimsulfuron 35 g/ha at 15-20 DAS + one HW at 40 DAS, fenoxaprop with safener 56 g/ha + ethoxysulfuron 18 g/ha at 20-25 DAS + one HW at 40 DAS and bispyribac 25 g/ha at 20-25 *fb* one HW at 40 DAS in sub plot were tested in split plot design, and replicated thrice. Rice established by zero-till DSR with anchored residue had minimum density and dry weight of grasses, sedges, broad-leaves and maximum weed control efficiency, yield attributes, grain yield (4562 and 4785 kg/ha), economics and moisture use efficiency. Among weed management methods, application of pendimethalin 1000 g/ha followed by (*fb*) azimsulfuron 35 g/ha at 15-20 DAS + one hand weeding at 40 DAS proved to be most effective in lowering the weed density of grassy and non-grassy weed population and their biomass, and thus enhancing the weed control efficiency, yield attributes, grain yield (5451 and 5542 kg/ha), economics and moisture use efficiency during both the years of experimentation. Due to 40 cm of whaet anchored residue, population of broad-leaf and sedges were less but grasses were the most abundant in population as well as biomass during both years of experimentation. Although, the result of this trial confirm the weed effect on the grain yield of rice, the finding also prove the integration of establishment methods and weed management method effectively control the weeds and enhance the yield of DSR

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Efficacy of herbicides against weeds in direct seeded rice in Kymore plateau region of Madhya Pradesh

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The experiment was carry out at research farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during *kharif* season of 2011 under edaphic and climatic conditions of Jabalpur (M.P.). It is off the record as "Kymore Plateau and Satpura Hills" agro climatic zone as per norms of National Agriculture Research Project (ICAR), New Delhi. The experiment was laid out in a 'Randomized Complete Block Design' with 8 treatments *viz.* glyphosate 1500 g/ha, pendimethalin 1500 g/ha, glyphosate *fb* bispyribac-na 1500 *fb* 20 g/ha, pendimethalin *fb* bispyribac-na 1500 *fb* 20 g/ha, glyphosate *fb* 2, 4-D 1500 *fb* 500 g/ha, pendimethalin *fb* 2, 4-D 1500 *fb* 500 g/ha, hand weeding and weedy check and replicated three times. Soil of the experimental field is clayey in texture, neutral in reaction (pH 7.1), medium in organic carbon (0.64) and available N (372 kg/ha), and available P (17.45 kg P_2O_5/ha) and high in available K (297 kg K_2O/ha). *Echinochloa colona, Dinebra retroflexa* and *Cyperus iria* were the rampant in the experimental field which was cropped with direct seeded upland rice. Beside these *Phyllanthus niruri* and *Eclipta alba* also marked their presence in small numbers.

Highest total weed population and weed biomass recorded maximum in weedy check plots. Plots receiving pendimethalin *fb* bispyribac-sodium (1500 g/ha *fb* 20 g/ha) at 1 DAS and 15 DAS recorded minimum weed population as well as dry biomass of weeds due to excellent control of weeds from early growth stage upto the end of critical period which was free from crop weed competition. The maximum weed control efficiency was noted in plots receiving hand weeding twice (20 and 40 DAS), which was closely followed by pendimethalin *fb* bispyribac-sodium (1500 g/ha - 20 g/ha) at 1 DAS and 15 DAS.

Yield attributing traits *viz.*, number of effective tillers per metre length, number of grains/panicle and number of filled and unfilled grains per panicle were higher in plots receiving hand weeding twice followed by pendimethalin *fb* bispyribac sodium (1500 g/ha *fb* 20 g/ha) at 1 DAS and 15 DAS and proved superior over rest of the treatments. The seed and straw yield was lowest in the plots receiving no weed control measures (weedy check) due to severe competition of weed and crop. Weed free treatment produced the maximum seed and straw yield and proved its superiority over the remaining treatments. Among the herbicidal treatments, application of pendimethalin bispyribac-sodium (1500 g/ha *fb* 20 g/ha) applied as pre and post emergence recorded higher seed and straw yield as compared to other herbicidal treatments. Application of pendimethalin *fb* bispyribac-sodium (1500 g/ha *fb* 20 g/ha) also proved variable from economic point of view eye-catching greater net monetary return with B:C ratio as comparable to hand weeding twice (20 & 40 DAS).

Efficient weed management practices in aerobic rice culture

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Aerobic rice systems can substitute the conventional rice cultivation system in the wake of water shortage and energy crises. The major constraint in the success of aerobic rice is high weed infestation to pose serious competition for resources to the crop in early stages and cause heavy reduction in yield. On an average, reduction in grain yield up to 80% and sometimes also results in complete failure of the crop was found under aerobic conditions. Under such environment weeds are managed by manual weeding and by using herbicides to certain extent in sequential manner. Usage of effective herbicides in aerobic conditions improves grain yield besides overcoming the labour problem. With above consideration it was felt necessary to plan a field trial to study the efficient weed management practices on growth, yield and economics of aerobic rice. Therefore, a field experiment was conducted during *Kharif* 2014 at agricultural research farm of Institute of Agricultural Sciences, BHU, Varanasi, in Randomized Block Design in three replications, consist of eleven treatment combination *viz.* pendimethalin (30 EC) at 1.00 kg/ha + bispyribac-Na (10% SC) at 35 g/ha, pendimethalin (30 EC) at 1.00 kg/ha + 2, 4-D Na salt (80 WP) at 0.06 kg/ha, pendimethalin (30 EC) at 1.00 kg/ha + straw mulching at 4 t/ha, pendimethalin (30 EC) at 1.00 kg/ha + almix (CME + MSM) (20 WP) at 40 g/ha, butachlor (50 EC) at 1.5 kg/ha + bispyribac-Na (10% SC) at 35 g/ha, butachlor (50 EC) at 1.5 kg/ha + 2, 4-D Na salt (80 WP) at 0.06 kg/ha, butachlor (50 EC) at 1.5 kg/ha + straw mulching at 4 t/ha, butachlor (50 EC) at 1.5 kg/ha + almix (CME + MSM) (20 WP) at 40 g/ha, mechanical weeding at 20 and 45 DAS, need based hand weeding and un-weeded check. Outcomes of the study showed that among herbicidal treatments, pre-emergence application of pendimethalin at 1.00 kg/ha at 3-4 DAS *fb* bispyribac-Na at 35 g/ha at 15-20 DAS as post-emergence recorded significantly higher growth parameters like plant height, number of tillers/m^2, number of leaves/m^2, leaf area index, dry matter accumulation at all stages of observation along with yield attributing characters and yield of both grain and straw than rest of the treatments. Similarly significantly higher net returns and B: C ratio was observed with the same treatment. But maximum nutrient uptake by crop and minimum removal of nutrients by weeds was at par with mechanical weeding at 20 and 45 DAS. Nutrient uptake by both crop and weeds were directly influenced by the relative efficacy of weed management treatments. So, on the basis of one year experimentation it can be concluded that the application of pendimethalin at 1.00 kg/ha at 3-4 DAS *fb* bispyribac-Na at 35 g/ha was in direct correlation with weed control practices on crop growth, yields, economics and nutrient removal by both crop and weeds in aerobic culture.

Bio-efficacy of bispyric-sodium in growth and yield of transplanted rice – A review

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Rice, the most important staple food crop of India is cultivated under various ecosystems, *viz*. transplanted, direct sown and rainfed situations. In transplanted rice, weed infestations not only reduce the grain yield upto 45% but also quality of grain is impaired. The share of weed management cost is higher than other operations in transplanted rice. Though many pre-emergence herbicides are available for controlling weeds, the need for post-emergence herbicide is often realized to combat the weeds emerged during later stages of crop growth. Moreover, due to increasing problem of labour availability for rice cultivation, use of post-emergence herbicide has greater potential for effective weed management and higher yield.

In this context, a field experiment is conducted during summer 2011 at Zonal Agricultural Research Station, V. C. Farm, Karnataka to evaluate the bio-efficacy of the bispyribac sodium herbicide in transplanted rice and results indicated that application of bispyribac sodium 10% SC at 35 g/ha at 15 DAT was found effective against all types of weeds (*Cyperus difformis, Cyperus iria, Fimbristylis woodrowii, Echinochloa crusgalli, Cynodon dactylon, Rotala densiflora* and *Eclipta alba*) and recorded higher weed control efficiency. However, significant higher grain and straw yield were found in plots treated with bispyribac sodium 10 % SC at 25 g/ha at 15 and was being at par with two hand weeding at 20 and 40 DAT as compared to weedy check.

Furthermore, a research experiment is conducted to evaluate herbicide bispyribac sodium in transplanted rice varieties 'ASD 16' and'ADT 37' during 2010 and 2011 and reports suggested that effect of post-emergence application of bispyribac-sodium at 25 g/ha on total weed population were at par with the higher doses of bispyribac-sodium at 35 and 50 g/ha during both the years of study. The weed control efficiency and weed index under bispyribac sodium at lower dose were also comparable with that of higher doses indicating the sufficiency of bispyribac sodium at 25 g/ha for effective weed management in transplanted rice. Post-emergence application of bispyribac sodium at 25 g/ha recorded higher grain yield which was also at par with higher doses of bispyribac sodium, twice hand weeding and weed free treated plots during 2010 and 2011.

From the experiments conducted by the above researchers it is concluded that bispyribac sodium 10% SC at 25 g/ha at 15 DAT is the best treatment among all other treatments at different doses except weed free in terms of highest number of tillers production, dry matter accumulation by crop plants and productivity of rice crop. So using bispyribac sodium 10% SC at 25 g/ha as post-emergence is an alternate options in transplanted rice in terms of weed control as well as productivity of rice.

Prevailing weed management practices in transplanted rice in Balaghat district of Madhya Pradesh

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Out of the total yield losses due to pests in India, weeds cause 33 per cent loss. Weeds compete with the crops for light, water, nutrients and space and consequently reduce the crop yield and product quality. The principal components that influence yield reduction are weed flora and density, duration of competition, management practices and climatic conditions. Rice is cultivated in different types of ecosystems ranging from shallow low lands to mid-deep low lands, deep water and uplands. Transplanting is the most prevalent method of rice cultivation in India which is getting replaced by other systems of cultivation. The weed flora associated with rice, utilize the ideal environment conditions of rice ecosystems to its advantage. Out of 3,02,500 ha cultivated area rice is grown in 2,45,000 ha area in Balaghat district and most of it is lowland transplanted rice. Some studies have indicated that uncontrolled weeds reduced grain yield by 62.6 per cent under transplanted rice (Singh *et al.* 2005). Experiments have shown that yields are comparable across all rice cultivation methods when competition from weeds was minimized. Many weeds which propagate by vegetative means are becoming dominant due to increased use of tractor and power tiller. Weeds like *Echinochloa crusgalli, E. colona* and *Sacciolepis* sp. having mimics with rice crop are appearing as major weeds in many rice growing areas of Eastern India. Moreover, shortage of labours, increased wages and lack of suitable weed control implements have compelled farmers to think for alternative strategies of weed management. Herbicides have been the obvious choice to the farmers, which has resulted in increased use of herbicides in India. But most of them are specific and work against narrow range of weed species (Mukherjee and Singh 2005) besides leading several problems in long run. In rice there is no single accepted weed control method for economic and effective management of weeds, hence a combination of several weed control methods under irrigated weed management strategy (IWM) is normally recommended. Some researchers are of the opinion that most of the farmers follow some kind of weed control in rice therefore a more realistic method of estimating yield losses would be to compare the added benefits due to additional weed control measures as compared with farmers weed control method. Intensive puddling beginning 15-20 days ahead of transplanting and continuous submergence eliminated the need for any weed control method in low land rice. It was observed that most of the farmers preferred chemical weed control as compared to manual weeding due to unavailability of labour and cost effectiveness.

Effect of three rice based cropping systems on weedy rice population under conservation agriculture

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Weedy rice is becoming a severe constraint in rice cultivation in Central part of India. It has high competitive ability with cultivated rice. Weedy rice infestation may cause significant rice yield loss of upto 74%. Controlling weedy rice through herbicides has not been successful hence other management strategies need to be developed.

Rice-wheat rotation occupies about 18 m ha in Asia of which 13.5 m ha are in Indo-Gangetic plain (IGP) of India (10 m ha), Pakistan (2.2 m ha), Bangladesh (0.8 m ha) and Nepal (0.5 m ha). A substantial rice-wheat system (1.06 m ha) exists in Kymore plateau and Satpura hills agro-climatic zone of central India (Madhya Pradesh) outside the Indian (IGP). But evidence is now appearing that the system productivity is plateauing and total factor productivity is declining due to fatigued natural resource base. The traditional method of crop establishment involves excessive tillage. The management of crop residue and soil organic matter is of prime importance in maintaining soil fertility and productivity. After rice and wheat harvest significant crop residue are left in the field, especially in the combined harvested area. These residues are mostly burnt in situ thus polluting the environment ad leading to wastage of precious resources. The farmers resort to have good seed bed and employ excessive tillage resulting in highest cost of cultivation, acceleration of soil erosion and compactness of sub soil. Such harmful effect of excessive tillage can be resolved by the conservation agriculture. It is greatly observed that problem of weedy rice is more under conservation agriculture practices. Infestation of weedy rice is also increasing across rice grown areas.

Field experiments were conducted at ICAR-DWR research farm during 2014-16 to compare the effect of rice based cropping systems (rice-wheat-greengram, rice-wheat-sesbania and rice-wheat-sunhemp) on the population of weedy rice. It was observed that weedy rice population was comparatively less (80%) in direct seeded rice under rice-wheat-greengram system in comparison to rice-wheat-sesbania and rice-wheat-sunhemp system. Hence, it may be stated that inclusion of greengram along with application of imazethapyr 100 gm/ha, in rice-wheat cropping system could be an effective strategy for managing weedy rice. This was due to the application of imazethapyr 100 gm/ha in greengram which controlled the germinated weedy rice plants while sesbania and sunhemp cover crops could not control the weedy rice.

Integrated weed management under system of rice intensification (SRI)

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Rice (*Oryza sativa* L.) is the principle cereal crop grown under manifold agro climatic condition throughout India and is of paramount importance so far as Indian economy is concerned. In India rice is the leading food crop of the world, cultivated over an area of about 44.14 mha with a production level of 106.65 mt and productivity of 2.60 t/ha. 90% of rice worldwide is grown and consumed in Asia. Weeds infestation is one of the major constrains of SRI due to wide planting geometry and moist environment, thereby reducing rice yield up to 69.15%. The dominant weeds in fields were *Echinochloa* sp., *Panicum repens, Cynodon dactylon, Bracharia mutica, Digitarias anguinalis* and *Leptochloa chinensis* among grasses, *Eclipta alba, Commelina communis* and *Ludwigia parviflora* as among broad-leaf weeds and *Cyperus* sp. as sedge. An integrated weed management is defined as combinations of two or more weed control measures at low inputs in order to reduce weed competition in rice below an economical threshold level. Use of preventive methods and cultural practices such as crop simulation through nutrient application, method of rice sowing, planting time, plant population, and weed competitive cultivars have been recommended for minimizing impact of weeds on crop yield. The use of herbicide rotation, herbicide-resistant crops, bio-herbicides, and their integration with hand tools or agricultural implements should be encouraged for better weed control efficiency. Herbicides by virtue of their merit will be an important component of Integrated Weed Management (IWM). With judicious use and clever integration with other methods of weed management, herbicides will enable farmers to achieve better weed control at reduced cost and very often with enhanced productivity of crops.

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Integrated weed management in rice

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Rice is cultivated during the *Kharif* and *Rabi* season after receiving monsoon. Tank and canal water from PeriyarVaigai Command area is the main source of irrigation. Soil is clay loam in texture and medium in nitrogen (310 kg/ha), and potassium (146 kg/ha) and high in phosphorous (22.5 kg/ha). The trial was taken up during September, 2017 under irrigated condition in T. Puthur village of Kalligudi block, Madurai District. During the cultivating period 285 mm of rainfall was received which accounts 12 rainy days. The treatments are T1: Farmer's practice (Farmers generally go for two hand weeding during 20 and 45 days after transplanting. Sometimes, third weeding is also resorted to which is not economical one), T2: Pre-emergence herbicide + hand weeding (butachlor is applied at 1 litre/acre, mixed with sand and uniformly broadcasted on 3 DAT and sufficient soil moisture should be ensured in the field. The water will be drained during the next day. Butachlor is pre-emergence herbicide, effective against broad-leaved weeds.This will be followed by one hand weeding on 25–30 DAT), T3: Early post-emergence herbicide + hand weeding (bispyribac-sodium is applied at 60–80 ml/ acre as a tank mix and sprayed over the soil during 12–15 DAT when the weeds are at two leaf stage. This will be followed by one hand weeding on 35–40 DAT. The rice variety BPT 5204 was used in this trial. The grain yield was higher (5418 kg/ha) in technology T3 closely followed by T2 (5315 kg/ha). The grain yield was very low in farmers' practice where they have gone for two hand weeding. The higher yield in T3 and T2 is may be due to the weed free environment the crop enjoyed due to the timely weed management whereas; in T1 it was not possible due to the non-availability labourers during the season time, timely weeding was not possible, which has reflected in the yield. Moreover, the weed population and weed DMP are higher in farmers' practice during the critical stages of 20 DAT, 40 DAT and 60 DAT which coincided with active tillering, panicle initiation and flowering and the weeds would have exerted severe competition to the crop which directly correlated with the lower yield. As regards, T3 and T2 the competition by the weeds were very much alleviated by the application of pre and post-emergence herbicides and would have aided in increased absorption of water and nutrients in the weed free environment and thus resulted in increased yield. With regard to economics, the cost of cultivation was higher in farmers' practice with ` 59500/ha due to the increase wages of labourers whereas the herbicides were cost effective, which may be the reason for increased BCR in T2 and T3.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Bio-efficacy of Propanil 80% DF against weed flora of direct-seeded rice in new alluvial zone of West Bengal

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Direct seeded rice (DSR) is gaining popularity due to its potentiality of saving resources (labour wages, water, energy etc.), less emission of green house gases and improvement of soil physical properties. However, weed is the major constraint for DSR. Huge yield loss (may be up to 100%) occurs due to weed infestation. A field experiment had been conducted to assess the effect of Propanil 80% DF on bio-efficacy of DSR during *Kharif* season of 2015 and 2016 at the Instructional Farm ($22^0 56^{Œ§}$ N, $88^0 32^{Œ§}$ E and 9.5 m above MSL), Jaguli, B.C.K.V. Nadia, West Bengal. The experiment was laid out in randomized block design (RBD) with seven weed control treatments along with weedy check replicated thrice. Variety 'MTU 7029' (Swarna Masuri) was used for this experiment. Treatments included different doses of Propanil 80% DF (1000, 2000, 3000 and 4000 g/ha), Oxyfluorfen 23.5% EC 240 g/ha, Cyhalofop-butyl 10% EC 80 g/ha, hand weeding and weedy check. All the doses of the tested formulation of Propanil and Cyhalofop-butyl were applied at 15 days after sowing (DAS) in both the seasons under sufficient moisture, however, Oxyfluorfen had been applied at 3 DAS. Hand weeding was done twice at 15 DAS and 30 DAS.

Experimental field dominated with mixed weed flora. Among the grassy weed - *Echinochloa colona, Echinochloa formosensis, Brachiaria mutica, Panicum repens, Leptochloa chinensis* and *Digitaria sanguinalis*; among sedges - *Cyperus rotundus, Cyperus difformis* and *Fimbristylis miliacea* and among broad-leaf weeds - *Ludwigia parviflora, Commelina benghalensis, Eclipta alba, Cleome viscose, Physalis minima, Euphorbia hirta, Ageratum houstonianum* and *Phyllanthus niruri* were found.

All the weed management treatments were found to be superior over weedy check due to reduction in weed density. Hand weeding twice recorded to be the best weed control measure. Propanil 4000 g/ha was the best herbicidal treatment followed by Propanil 3000 g/ha due to lower weed densitywhich were found to be at par with twice hand weeding. Maximum weed density was recorded under weedy check where the density of grassy weed was comparatively higher than broad-leaf and sedge weeds. Twice hand weeding recorded the highest weed control efficiency of 90.90% and 92.83 at 45 DAS and 86.69 and 86.27 at 75 DAS in 2015 and 2016 respectively which was at par with Propanil 4000 g/ha and Propanil 3000 g/ha .

Twice hand weeding treatment recorded the highest grain yield (4.52 and 4.48 t/ha in 2015 and 2016 respectively) among all the treatments; however, weedy check treatment produced the lowest (2.63 and 2.76 t/ha in 2015 and 2016 respectively). Among herbicidal treatment, Propanil 4000 g/ha evidenced significantly higher grain yield which was statistically at par with Propanil 3000 g/ha. From the experiment, it can be concluded that Propanil 3000 to 4000 g/ha can be used for effective management of grass, sedge and broad-leaved weeds.

Weed management in direct seeded rice (*Oryza sativa*) + brahmi (*Bacopa monnieri*) intercropping in *tarai* area of Uttrakhand

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Rice (*Oryza sativa* L.) is a member of graminae family and is relished as staple food by majority of world's population. In India, rice occupied 43.94 million hectares area with a production of 106.54 million tonnes. Direct-seeded rice offers the advantage of faster and easier planting, reduce labour and hence less drudgery and more efficient water use. The risk of yield loss from weeds in direct-seeded rice is greater than transplanted rice. Nowadays, intercropping has become one of the popular methods in agricultural system due to the more efficient use of resources and its role in reduction in weeds interference and other pests.

An investigation was carried out to evaluate the effect of rice + brahmi intercropping on yield, yield attributes and economics of the intercropping system during rainy seasons of 2015 and 2016. The experiment was carried out in Randomized Block Design by taking ten treatments with three replications *i.e.* two ratios 1:1 *i.e.* rice + brahmi in additive series (where brahmi crop was sown at the spacing of 40 cm and one row of rice was sandwitched between two rows of brahmi at 20 cm) and 2:1 *i.e.* rice + brahmi in replacement series (where brahmi crop was sown at the spacing of 20 cm after two rows of rice at 20 cm) and in both ratios, four different weed management practices are taken (pendimethalin 1 kg/ha + 2 hand weedings (HW), pendimethalin 1 kg/ha and pendimethalin 1 kg/ha + cyhalofop-butyl 20 g/ha + 1 hand weeding) and one treatment of sole rice and sole brahmi. The rice variety '*Pant-18*' and brahmi variety '*CIM Jagriti*' was sown using a seed rate of 17 kg/ha and 3.3 t/ha in additive series and 21 kg/ha and 2.5 t/ha in replacement series, respectively. The recommended fertilizer doses of rice (120:60:40) were applied. Weed population and weed dry weight were recorded at 30 days after sowing.

Lowest weed density, dry weight and highest weed control efficiency were recorded in pendimethalin followed by (*fb*) cyhalofop-butyl *fb* one hand weeding at 45 days after sowing in 2:1 row ratios. Results also indicated that intercropping of rice with brahmi, exhibited greater potentiality and resulted in higher values of most of studied criteria of both rice and brahmi *viz*. plant height, dry matter accumulation, number of nodes, number of branches, number of panicles/m^2 and 1000 grain weight. Dry herbage yield of brahmi and grain yield were highest in sole crop of rice and brahmi. Furthermore, the value of land equivalent ratio (LER) and area time equivalent ratio (ATER) was found highest in treatment pendimethalin *fb* cyhalofop-butyl *fb* one hand weeding at 45 days after sowing in 1:1 ratio of direct seeded rice and brahmi during both years. The highest net returns and benefit cost ratio was found in the treatment pendimethalin *fb* cyhalofop-butyl *fb* one hand weeding at 45 DAS in 1:1 ratio of rice and brahmi during both the years of experimentation.

Weed management strategies for direct-seeded rice

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The study was conducted at Indira Gandhi Krishi Vishwavidayalaya, Raipur (Chhattisgarh) during wet season of 2014 and 2015 in silty clay loam soil. In all 8 treatments comprised application of XR-848 benzyl ester 2.5% EC (w/v) at 25 ml/ha, XR-848 benzyl ester 2.5% EC (w/v) at 31.25 ml/ ha, XR-848 benzyl ester 2.5% EC (w/v) at 37.5 ml/ha, bispyribac-Na 100% SC at 25 ml/ha, azimsulfuron 50% DF at 35 g/ha, pyrazosulfuron ethyl 10% WP at 20 g/ha, Hand weeding at 20 & 40 days after sowing (DAS) and Untreated control. The experiment was laid out in RBD with three replications. An introspection to the weed flora of the experimental plot revealed that grasses, sedges and broad-leaved weeds were dominated in the rice crop from early stage to harvest. The major weed species observed in the experimental field were *Echinochloa colona* L., *Ischaemum rugosum, Leptochloa chinensis, Aeschynomene indica* L., *Alternanthera triandra, Cyanotis axillaris* L., *Commelina benghalensis* L., *Eclipta alba, Ludwigia parviflora, Spilanthus acmella* Murr, *Cyperus rotundus* L., *Cyperus iria L., Cyperus difformis* L, and *Fimbristylis miliacea* (L.). Fourteen weed species belonging to 7 families were naturally found in the experimental field. The scenario of weed dominancy was different in both the years. The dominancy of sedges was more than other weed species during 2014-15. However, broad-leaved weeds were found more dominated weed species during 2015-16.
Results revealed that hand weeding at 20 & 40 DAS, applications of bispyribac-Na at 25 ml/ha and XR-848 benzyl ester at 37.5 ml/ha were found similar with respect to weed density, weed biomass, weed control efficiency, yield attributes and yield of direct seeded rice as compared to other weed management practices. Among the herbicides, applications of bispyribac-Na at 25 ml/ha or XR-848 benzyl ester at 37.5 ml/ha or XR-848 benzyl ester at 31.25 ml/ha were found to be equally effective with respect to weed density, weed biomass, weed control efficiency, yield attributes and yield of direct seeded rice. In concerning to XR-848 benzyl ester, the dose of 31.25 ml/ha of XR-848 benzyl ester was found effective when sedges were dominated in direct seeded rice. While, the dominancy of broad- leaved weeds in addition to sedges were effectively controlled by the dose of 37.5 ml/ha of XR-848 benzyl ester.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Management of complex weed flora in dry direct-seeded rice

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Rice (*Oryza sativa* L.), being the principal food crop in India plays an important role in ensuring food security. In India, traditional rice-establishment method involves manual/mechanical transplanting of seedlings into puddled soils which is water- and labour-intensive. The looming scarcity of resources for agriculture due to competition with other non-agricultural sectors, drives the researchers towards the identification and adoption resource-conserving rice production technologies. Direct-seeded rice (DSR) has emerged as such technology that potentially saves substantial amount of water and labour requirements, besides providing ecological benefits. Weeds are the most important constraint limiting the productivity of DSR as the losses due to weeds ranges from 16-80% and even complete crop failure is not uncommon. Therefore, identification and adoption of appropriate weed-management options are of paramount importance in realizing higher productivity of DSR.

Chemical weed management with selective herbicides is the most popular method as it provides timely, effective and economical control over the other methods. However, repeated use of particular herbicide (s) with similar mode of action may result into shift towards more difficult-to-control or even herbicide-resistant weed flora. Sequential application of different herbicides (pre-emergence followed by post-emergence) or mixture of herbicides with different mode of actions or brown manuring (co-culture of *Sesbania* with rice and its subsequent killing with 2, 4-D) has been reported to control various weed species and enhance rice yield.

Keeping the above facts in view, an attempt has been made to identify appropriate weed-control option (s) in dry DSR. The predominant weed flora observed in DSR included *Echinochloa colona* L., *E. crus-galli* L. and *Leptochloa chinensis* L. among the grasses; *Eclipta alba* L., *Digera arvensis* L. and *Trianthema portulacastrum* L. among the broad-leaved weeds; and *Cyperus iria* L. and *C. rotundus* L. among the sedges. Various weed-control options significantly reduced total weed density and biomass by 68.0-84.5% and 71.6-86.7%, respectively as compared to unweeded control at 60 days after sowing (DAS). Sequential application of pendimethalin (1 kg/ha) as pre-emergence followed by (*fb*) a mixture of penoxsulam + cyhalofop-butyl (130 g/ha) as post-emergence (25 DAS) being at par with brown manuring (BM) *fb* application of Almix (4 g/ha) at 40 DAS exhibited highest reduction in weed growth and lowest nutrient (N, P and K) removal by weeds. This treatment (pendimethalin *fb* penoxsulam + cyhalofop-butyl) significantly improved the crop growth parameters, *viz.* plant height, number of tillers, leaf area, dry matter accumulation and mean crop growth rate; yield attributes and yield, crop nutrient uptake and net returns followed by sequential application of pendimethalin (1 kg/ha) *fb* bispyribac-sodium (20 g/ha) and BM *fb* Almix.

Based on the findings of the investigation, it can be inferred that sequential application of pendimethalin (1.0 kg/ha) *fb* penoxsulam + cyhalofop-butyl (130 g/ha) may be an effective weed-control strategy in DSR with higher crop growth, yield components and ultimately improved productivity.

Sustainable approaches of weed management

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Weeds are considered to be a potential threat to crop production causing more than 45% loss in yield of field crops. Weed management involves one third of total cost of production. The usage of herbicides is increasing due to non availability of labour and at the same time leads to ecological imbalances in terms of weed shift, herbicide resistance in weeds and pollution. Sustainable development conserves natural resources and is environmentally non degrading, technically feasible, economically viable and socially acceptable method. The sustainable approaches mainly involve making best use of the renewable natural resources without involving synthetic chemicals and developing knowledge and skills which should be suitable to local conditions and capacity. Proper density of crops which can be achieved by increasing the seed rate, spatial arrangement can control weeds to some extent due to modification of micro climate. Other cultural methods like green manure *in situ*, intercropping, crop rotation have the capability of providing crops greater competitive ability and suppression of weeds. The by product of the plant and animal matter is also effective in controlling weeds. Various mechanical approaches such as off season ploughing, soil solarization, stale seed bed provide sustainable way to control weeds. The incorporation of dhanicha and azolla with the cono weeder in SRI method also results in higher weed control. Organic mulches and black polythene have been used to control weeds in organic production systems. Surface application of rice residue was also found to significantly reduce weed population, weed dry matter production. The allelopathy of crops against weed and weeds against weeds can be exploited for ecological weed control. Biofertilzers like azolla and pressmud was found to have least weed count and highest weed control index in rice crop by preventing interception of light by weeds. Further a variety of natural enemies like insects can be employed to control weeds particularly alien weeds. Further bioherbicides mainly consisting of phytopathogenic fungi, bacteria have enormous potential to control weeds in a sustainable manner. The use of bioherbicides is an emerging tool, to control weeds in organic farming and has the potential in controlling herbicide resistant weed biotypes. Though, herbicide resistant crops of canola, maize, cotton and soybean accounted for 77% of the Genetically Modified crops, there are risks associated with them. No single method can be able to meet the required weed control in a field keeping in view the diversity of weed species which necessitates the combination of all the ecologically feasible methods based on crops, cropping system, weed species, socio economic condition of farmers.

Optimizing dose of butachlor in transplanted rice under terai region of West Bengal

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Rice is the most vital and comprehensively grown food crop in the world. It is the staple food of more than 60% of the world population. India is accounting almost 40% of the world rice production. Weed menace is one of the important yield restrictive biotic constraints in transplanted rice, particularly during initial stages of plant growth. The various weed dynamics (grasses, broad-leaved and sedges) can affect the yield drop to a great extent. Hand weeding become impossible and costly affairs due to insufficiency of labour and continuous rain during *Kharif* season. Farmers of terai region generally use butachlor as pre-emergence herbicides to control weed flora in low land rice field. However, due to application of improper rate of butachlor, farmers could not get satisfactory result. Keeping the above fact in mind a field experiment was conducted during *Kharif* season of 2017 at the Instructional farm of Uttar Banga Krishi Viswavidyalaya, Cooch Behar, West Bengal to find out optimum dose of butachlor 50% EC on transplanted rice. The experiment was laid out in randomized block design with seven treatments and replicated thrice. Observations on species wise weed count (per sq. m area) was recorded at initial (before herbicide application) followed by 30 and 60 days after application (DAA) of butachlor from each plots using 1 m^2. Dry weight of weeds from each plot was recorded 60 days after application of butachlor. Weed control efficiency (WCE) was calculated on the basis of data recorded at 30 & 60 days after application of butachlor. Yield attributes and grain yield of rice was recorded at the time of harvesting. Major weed flora found in the experimental field was *Echinocola colona, Echinocola crusgalli, Cyperus iria*, *Monochoria vaginalis* and *Ludwigia parviflora*. Results of the experiment revealed that application of butachlor at 2.5 kg/ha recorded highest (68.93%) degree of weed control efficiency with disregard to the species without showing phyto-toxicity followed by butachlor 50% EC at 2.0 kg/ha and butachlor 50% EC at 1.5 kg/ha. Weed control efficiency was more upto 30 days after application of herbicides there after efficiency was reduced irrespective of herbicide dose. Application of higher doses of butachlor than 2.5 kg/ha did not record significant improvement in reducing weed density and dry weight. Significantly higher yield attributes and grain yield (4.09 t/ha) was obtained with the application of butachlor 50% EC at 2.5 kg/ha, which was followed by butachlor 50% EC at 2.0 kg/ha and butachlor 50% EC at 1.5 kg/ha.

Integrated weed management on weed growth and yield of direct-seeded rice

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The main disadvantage of direct-seeded rice is high weed infestation, because both weed and crop seeds emerge at the same time and compete with each other from germination, resulting yield reduction 50 to 100% (Mishra and Singh 2007, Rao *et al*. 2007), Herbicides look better than other methods because of their performance in decreasing weed competition, easy usage and low cost of weeding. Therefore effective and timely weed control is a key component for success of production of direct-seeded rice. Weed problem in direct seeded rice can be managed by implementing integrated weed management. A field experiment was conducted during the *Kharif* season of 2015 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh to identify the best integrated weed management method for reducing density and dry weight of weeds and optimizing the yield of DSR. The experiment was laid out in a randomized block design, comprising 10 treatments and replicated trice. Rice variety *'MTU-7029'* was sown by zero till drill during the last week of June following the seed rate of 30 kg/ha and 20 cm row-row spacing. A recommended dose of fertilizer (150 kg N, 60 kg P_2O_5 and 60 kg K_2O) was applied using urea, single super phosphate and muriate of potash during experiment. Data on weeds and yields were recorded. Duncan Multiple Range Test (DMRT) was used for comparing treatment means.

At 90 DAS, Penoxsulam 35 g/ha at 10 DAS *fb* 1 HW at 35 DAS had lesser total density and dry weight of weeds in comparison to penoxsulam 35 g/ha at 20 DAS *fb* 1 HW at 35 DAS. However, bispyribac Na 12.5 g/ha + azimsulfuron 15g/ha at 10 DAS *fb* 1 HW at 35 DAS recorded lower total density and dry weight of weeds as compared to bispyribac Na 12.5 g/ha + azimsulfuron 15g/ha at 20 DAS *fb* 1 HW at 35 DAS. Penoxsulam 35 g/ha at 10 DAS *fb* 1 HW at 35 DAS had higher weed control efficiency and lower weed index in comparison to penoxsulam 35 g/ha at 20 DAS *fb* 1 HW at 35 DAS. Penoxsulam 35 g/ha at 10 DAS *fb* 1 HW at 35 DAS had higher grain yield in comparison to penoxsulam 35 g/ha at 20 DAS *fb* 1 HW at 35 DAS. It was concluded that penoxsulam 35 g/ha at 10 DAS *fb* 1 HW at 35 DAS was most effective for controlling weeds and improving grain and straw yields of DSR.

Effect of nutrient levels and weed management on weed dynamics and yield of hybrid rice

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The experiment was laid out in split-plot design and replicated thrice at Dr. Rajendra Prasad Central Agricultural university, Pusa, Bihar. The treatments comprised three nutrient levels *viz.*, 100:50:30 kg NPK/ha, 120:60:40 kg NPK/ha and 140:70:50 kg NPK/ha in main plot and five weed control treatments *viz.* weedy check, hand weeding (25 and 50 DAT), conoweeder (25 and 50 DAT), pretilachlor at 0.5 kg/ha (pre-emergence) and pyrazosulfuron at 40 g/ha (post-emergence) in sub-plot. The growth parameters, *viz.* plant height and plant dry matter production were found to be maximum at F_3 level of fertilizer followed by F_2 and F_1 level of fertilizers. Whereas, weed management practices maximum value of these parameters occurred in hand weeding which was found at par with conoweeder except at 30 DAT and significantly higher than pyrazosulfuron and pretilachlor. The yield attributes, *viz.* number of tillers/m^2, length of panicle (cm) and number of grains per panicle were significantly higher at F_3 level of fertilizer than F_2 and F_1 level of fertilizers. Among the weed control treatments, hand weeding recorded higher number of tillers/m^2, length of panicle and number of grains/panicle which was found at par with conoweeder and significantly surpassed over pyrazosulfuron and pretilachlor. The grain and straw yields recorded at F_3 (5.77 t/ha and 8.17 t/ha) and F_2 (5.56 t/ha and 7.92 t/ha) level of fertilizer being at par and both produced significantly higher grain and straw yields than F_1 level of fertilizer (5.23t/ha and 7.45 t/ha). Among weed control treatments, maximum grain and straw yields were recorded in hand weeding (6.08 t/ha and 8.53 t/ha) being at par with conoweeder (5.96 t/ha and 8.36 t/ha) and produced significantly higher grain and straw yields than pyrazosulfuron (5.63 t/ha and 7.94 t/ha) and pretilachlor (5.41 t/ha and 7.63 t/ha). Harvest index did not differ significantly among fertilizer levels and weed control treatments. Weed population increased with increasing the fertilizer levels and recorded significantly higher value at F_3 level of fertilizer than F_1 level of fertilizer. Among the weed control treatments, hand weeding recorded significantly lower weed population and weed dry biomass than conoweeder, pyrazosulfuron and pretilachlor except 30 DAT. Among the weed control treatments, hand weeding although recorded maximum gross return (` 64438/ha) but was found at par with conoweeder (` 63122/ha) and pyrazosulfuron (` 59687/ha) and in turn significantly higher than pretilachlor (` 57289/ha). However, higher net return was registered under conoweeder (` 41362/ha) followed by pyrazosulfuron (` 38226/ha), hand weeding (` 38022/ha) and pretilachlor (` 36429/ha) but net return per rupee investment recorded in hand weeding (1.44) was significantly lower than conoweeder (1.89), pyrazosulfuron (1.77) and pretilachlor (1.74).

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Performance of direct-seeded hybrid rice under different mulches

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A field experiment was carried out on the Agronomy farm of College of Agriculture, Dapoli to find out the effect of different mulches on density and growth of weeds and yield of direct seeded hybrid rice during *Kharif* season of 2017. The experiment was carried out in Randomized Block Design with three replications and was comprised ten treatments *i.e.*, M_1- No mulch and no weed management, M_2- no mulch with weed management, M_3- paddy straw mulch at 5 t/ha at 20 DAS + one hand weeding at 40 DAS, M_4- *Glyricidia maculata* leaves mulch at 5 t/ha at 20 DAS + one hand weeding at 40 DAS, M_5- black polythene mulch (7 micron), M_6- silver polythene mulch (7 micron), M_7- transparent polythene mulch (7 micron), M_8- black polythene mulch (25 micron), M_9- silver polythene mulch (25 micron) and M_{10}- transparent polythene mulch (25 micron).

Results revealed that, treatment M_2 recorded significantly lower number of grasses, sedges, broad-leaf weeds and total weed flora than rest of the treatments except treatment M_9 for sedges at 30, 90 DAS and at harvest, treatments M_3 and M_4 for grasses and treatments M_3, M_4, M_5, M_6, M_8 and M_9 for sedges at 60 DAS. Among different mulches, treatment M_9 significantly reduced density of grasses, sedges, BLW's and total weed flora than rest of the treatments, except treatments M_8, M_6 and M_5 for grasses at 30 DAS, treatments M_8 and M_6 for sedges at 30 and 90 DAS, treatments M_8 for BLW's at 30 DAS and for total weeds at 90 DAS and at harvest, for grasses at 90 DAS and treatments M_8, M_6, and M_5 for BLW's at 90 DAS and at harvest. At 60 DAS treatment, M_3 significantly reduced the density grasses, BLW's and total weed flora than rest of the mulch treatments, except treatment M_4 for grasses and total weeds, and treatments M_4, M_8 and M_9 for BLW's.

Treatment M_2 significantly reduced the dry weight of grasses, sedges, BLW's and total weeds compared to rest of the treatments except treatments M_3 and M_4 for grasses and treatments M_4 for sedges at 60 DAS. At 60 DAS among different types of mulches, treatments M_3 and M_4 remained statistically at par with each other and found significantly superior over rest of the mulch treatments for dry matter weight of grasses, BLW's and total weed flora. In case of sedges, M_3 found significantly superior over rest of the mulch treatments. At harvest among different mulches, treatment M_9 recorded significantly less dry weight of grasses, sedges, BLW's and total weed dry weight than rest of the mulch treatments, except treatments $M_{8,}$ M_6 and M_5 for grasses and treatment M_8 and M_6 for sedges and BLW's.

Treatment M_9 recorded significantly higher grain, straw and total biological yield over rest of the treatments except treatments M_8, M_6 and M_5 for grain and straw yield and treatments M_8 and M_6 for total biological yield, which were statistically at par with treatment $M_{9.}$

Cultivation method and weed management influenced on yield of scented rice

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The field experiment on "Cultivation method and weed management influenced on yield of scented rice" was conducted during *Kharif* 2014 at the Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raj Mohini Devi College of Agriculture and Research Station, Ajirma, Ambikapur, Surguja (C.G.). Treatments comparised of three method of rice cultivation, *viz.* transplanted, direct seeding and lehi method as main plot and six weed management practices, *viz*. weedy check, two hand weeding at 30 and 50 DAS, pretilachlor at 700 g/ ha as a pre-emergence, oxadiargyl at 80g/ha as a pre-emergence *fb* ethoxysulfuron at 15 g/ha as a post-emergence, pretilachlor at 700g/ha as a pre-emergence *fb* ethoxysulfuron at 15g/ha as a post-emergence and anilofos at 0.5 kg/ha as a pre-emergence as sub-plot treatments with split plot design with three replications.

The results revealed that weed population and its dry weight were not influenced by method of rice cultivation; however, these were higher under direct seeding over transplanting and lehi method. All the weed control treatments were found to be significantly superior over weedy check in reducing the density and dry matter accumulation. The minimum weeds, its weight and higher weed control efficiency were recorded with oxadiargyl at 80g/ha as a pre-emergence *fb* ethoxysulfuron at 15g/ha as a post-emergence followed by pretilachlor at 700 g/ha as a pre-emergence *fb* ethoxysulfuron at 15 g/ha as a post-emergence. These herbicidal treatments were as good as two hand weeding done at 30 and 50 DAS. The results also indicated that treatment oxadiargyl at 80 g/ha as a pre-emergence *fb* ethoxysulfuron at 15 g/ha as a post-emergence recorded significantly higher panicle/m^2, length of panicle and 100-seed weight over weedy check, which was statistically at par with pretilachlor at 700 g/ha as a pre-emergence *fb* ethoxysulfuron at 15 g/ha as a post-emergence and two hand weeding (30 and 50 DAS). This may be attributed to significantly lower weed density and dry matter accumulation of weeds. Transplanting of rice gave significantly higher grain yield (5.68 t/ha) *i.e.* 6.6% higher over direct seeded line sowing (5.32 t/ha). The differences between line sowing (direct sowing) and lehi method of rice cultivation (5.36 t/ha) was non-significant.

The intraction effect of cultivation method and weed management practices, transplanting method of rice followed by direct seeded line sowing with weed management practices by oxadiargyl at 80 g/ha as a pre-emergence *fb* ethoxysulfuron at 15g/ha as a post-emergence gave significantly higher grain yield than other treatments.

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Management of *Eichhornia crassipes* [(Mart.) Solms] under non-crop situation in wetland rice ecosystem

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The Kuttanad Wetland ecosystem is now receiving global attention as nature is at the peak of its beauty in this Ramsar site and for its recognition as Gobally Important Agricultural Heritage System (GIHAS). This ecosystem comprises not only the Vembanad Kayal but also a huge network of rivers, canals and drains. The paddy fields reclaimed from the Vembanad Kayal are highly fertile and more productive compared to other rice producing regions of the state. With less than 15% of the rice area, the region contributes more than 30% of the rice production of the state. Kuttanad is located at 9.027° N latitude and 76.025°E longitude, lying around 0.5 to 2.0 m below mean sea level. The soils are silty clay, entisols, and high in organic carbon (2.5-5.0%), available phosphorous and exchangeable potassium.

The agriculture of Kuttanad wetlands is also unique for its cultivation under below sea level conditions. Paddy cultivation in the tract is mainly done by draining water from the paddy fields using axial flow pump. Gravitational flow of water to the low land fields makes irrigation practically feasible as and when required. The difficulty associated with land preparation and water management is the entry of aquatic weeds from the water bodies to the low lying cultivated fields. Major aquatic weeds in the area include *Eichhornia crassipes, Salvinia molesta*, *Cabomba caroliniana*, *C. furcata*, *Pistia stratioites*, *Utricularia escoleta*, *Chara vulgaris* (Stonewort), *Ipomoea aquatic*, *Nymphaea stellata*, *Limnophylla heterophylla etc.*

Invasion and spread of *Eichhornia crassipes* in the water bodies and its proliferation through seed and offshoots in the low land fields during non-cropped situation affects further land preparation, sowing and crop establishment. Thick mat of the weed hinders machinery operation for tillage, puddling and transplanting. Management by mechanical weeders is too expensive in large paddy polders. Biological management using insects and pathogens is also not practically feasible under Kuttanad ecosystem. Hence, a study was undertaken to assess the response of water hyacinth to various herbicides under pot culture and field situations at Rice Research Station, Moncompu and in farmer's field. The objective was to identify herbicides or its combination for managing water hyacinth in paddy fields prior to sowing. As saline water intrusion occurs in Kuttanad during summer season, the effect of salinity on the growth of Echhornia was also studied.

Among seven herbicides and its combinations tried, penoxsulam and carfentrazone was found effective in drying and withering of leaves compared to glyphosate and 2, 4-D. It was observed that herbicidal combinations performed better compared to single molecule application. The study on the effect of salinity on the decay of *Eichhornia* revealed that 15-20% mortality could be obtained on exposure to 15 ppt for five days. There was no mortality at 1, 2 and 3 ppt even on exposure to 10 days. After 10 days there was 25-30% mortality at 3 ppt. Application of herbicides followed by deep tillage can be recommended as a management strategy prior to sowing in infested paddy fields. Inundating saline water for long periods depending on the electrical conductivity of river water can also reduce the proliferation and spread of water hyacinth.

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Efficacy of organic sources of nutrients and weed management on basmati rice productivity under sub-tropical conditions of Jammu region

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An investigation to study weed management in combination with organic sources of nutrients in basmati rice under sub-tropical conditions of Jammu region was conducted during *Kharif* seasons of 2015 and 2016 at research farm of AICRP-IFS, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu. The experiment was laid out in split-plot design with six sources of nutrients treatments in main plots and four weed management treatments in sub-plots with three replications each. The main plot treatments consisted of six sources of nutrients, *viz*. 50% Rec. NPK through fertilizer + 50% N through FYM + inorganic source of micronutrients as per soil test, 100% organics (100% Rec. N through different organic sources each equivalent to 1/3 of Rec. N *i.e.* FYM + vermicompost + non edible oil cake), 100% organics+ marigold for potato on border as trap crop and bottle guard as trap crop for frenchbean, 50% Rec. N through vermicompost + biofertilizers for N + rock phosphate to substitute the P requirement + PSB, 100% organics + VAM, 100% Rec. NPK + secondary and micronutrients based on soil test through inorganic fertilizer and sub plots comprised of four weed management treatments, *viz*. weed free, mustard seed meal 5t/ha, rice bran 4 t/ha and weedy check . Among the sources of nutrients in rice, application of 100% organics + VAM recorded the highest plant height (67.14 cm, 69.01 cm), dry matter accumulation (144.82 g/m^2, 146.94 g/m^2), number of tillers (161.36/m^2, 167.26/m^2) and grain yield (3.95 t/ha, 4.10 t/ha) which was statistically at par with 100% organics + marigold for potato on border as trap crop and bottle guard as trap crop for frenchbean and 100% Rec. N through different organic sources each equivalent to 1/3 of Rec. N *i.e.* FYM + vermicompost + non edible oil cake during both years of experimentation. Among the weed management treatments, application of mustard seed meal 5 t/ha, rice bran 4 t/ha and weed free treatment though at par with each other not only significantly enhanced the plant height (65.43 cm, 67.58 cm), dry matter accumulation (137.74 g/m^2, 140.07 g/m^2), number of tillers (147.07/m^2, 153.26/m^2) and grain yield (3.92 t/ha and 4.10 t/ha) of rice but also lowered the total weed density and total weed biomass at 30 DAT during both the years of cropping (2015 and 2016).

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Efficacy of herbicide mixtures in wet direct-sown rice

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Rice (*Oryza sativa* L.) is a principal source of food for more than half of the world population and for the people of Asia in particular. Transplanting is the most common method of rice establishment which requires huge amount of water and is a labour intensive method. Wet direct sown rice (W-DSR) is a viable alternative for transplanted rice. Weed is one of the major production constraints reducing crop yield up to 65% in direct sown rice which must be managed during the critical period of crop weed competition. Among different weed control methods, chemical weed control is most economic. Use of herbicide is becoming more popular in W-DSR because it is more effective, easy to apply, provides selective control, saves labour and cost. Hence, there should be a continuous effort to discover safest molecules and its mixtures which can effectively control broad-spectrum of weed flora.

The present investigation was conducted at ICAR-National Rice Research Institute, Cuttack (Odisha) during wet season of 2016. The soil of the experimental field was sandy clay loam in texture and neutral (pH 6.8) in reaction having 0.52% soil organic carbon, low nitrogen (215.4 kg/ha), medium phosphorous (48 kg/ha) and high potassium (322.7 kg/ha) content. The experiment was laid out in Randomized Complete Block Design with nine treatments *viz.* four herbicide mixtures (XR-848 benzyl-ester + cyhalofop-butyl 12% EC (w/v) at 120 (20 + 100) g/ha, XR-848 benzyl-ester + cyhalofop-butyl 12% EC (w/v) at 150 (25 + 125) g/ha, XR-848 benzyl-ester + cyhalofop-butyl 12% EC (w/v) at 180 (30 + 150) g/ha, XR-848 benzyl-ester + cyhalofop-butyl 12% EC (w/v) at 360 (60 + 300) g/ha), three alone herbicides (XR-848 benzyl-ester 2.5% EC (w/v) at 25g/ha, XR-848 benzyl-ester 2.5% EC (w/v) at 30 g/ha, bispyribac-Na 10% SC at 30 g/ha), one weed free and weedy check, replicated thrice. The test variety *'Naveen'* was sown at 20 cm apart rows on 13th June, 2016 and harvested on 6th October, 2016.

Among the weed control treatments, the weed free registered significantly highest value of growth parameters of rice *viz.* dry matter accumulation, number of tillers/m^2, leaf area index, crop growth rate, relative crop growth rate and yield attributing characters like effective tillers/m^2, panicle weight, number of grains/ panicle, number of filled grains/panicle, grain and straw yield. Among different herbicide treatments, XR-848 benzyl-ester + cyhalofop-butyl 12% at 150 (25 + 125) g/ha controlled the weeds effectively with lowest weed density, dry matter, weed index and having the highest weed control efficiency (82% at harvest). The highest grain yield was recorded in weed free plots (5.27 t/ha) which was at par with XR-848 benzyl-ester + cyhalofop-butyl at 150 g/ha (4.91 t/ha). The yield was negatively correlated to weed density, weed dry matter and weed index. All the herbicide mixtures recorded higher growth and yield parameters compared to sole application of herbicides.

Thus, the herbicide mixture XR-848 benzyl-ester + cyhalofop-butyl at 150 g/ha is found to be potential option and may be recommended for better weed control in W-DSR.

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Evaluation of new herbicide mixture (penoxsulam + butachlor) for managing weeds in transplanted rice

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Weeds directly reduce the crop yields and indirectly increase farm production costs through energy spent in controlling them. Herbicides have become a popular choice amongst the farmers' for managing weeds in almost all the crops. However with the increasing incidences of herbicide resistance being reported from across the globe, it has become imperative to use herbicides alternately or use herbicide mixtures that have different mechanism of action. Recently a new herbicide mixture product has been developed for managing weeds in rice that contains two recommended herbicides of butachlor and penoxsulam. The present investigation was carried during *Kharif* 2016 at the Experimental Farm of CSKHPKV, Rice and Wheat Research Centre, Malan to test the efficacy of this new herbicide mixture for managing weeds in transplanted rice. Eight weed control treatments, *viz.* penoxsulam + butachlor 717.5 g/ha (7 days after transplanting DAT), penoxsulam + butachlor 820 g/ha (7 DAT), penoxsulam 25 g/ha (8-12 DAT), butachlor 1500 g/ha (1-3 DAT), bispyribac sodium 25 g/ha (20 DAT), weed free condition, hand weeding twice (25 and 45 DAT) and weedy check were evaluated for weed control, yield and economics. The soil of the experimental field was silty clay loam in texture, acidic in reaction (pH 5.3), medium in available N (426 kg/ha), high in available P (44 kg/ha) and medium in available K (264 kg/ha). The weed flora of the experimental field comprised of *Echinochloa colona, Commelina benghalensis, Digitaria sanguinalis, Panicum dichotomiflorum, Aeschynomene indica, Ammannia baccifera* and *Alternanthera philoxeroides*. *Echinochloa colona* and *Commelina benghalensis* were the major weeds constituting 27.1 and 18.0% of total weed population, respectively. Results of the study revealed that plant height, total number of tillers, effective tillers, number of grains per panicle, grain weight per panicle, grain yield and straw yield was significantly higher when lower dose of new herbicide combination product (717.5 g/ha) was applied though this treatment was at par with the higher dose (820 g/ha) of this new herbicide combination product penoxsulam 25 g/ha, bispyribac sodium 25 g/ha, butachlor 1500 g/ha and weed free treatment. Maximum weed control efficiency and lowest dry matter accumulation by weeds was recorded in weed free condition. Abundance of weeds in weedy check lowered the grain yield of rice by 35.45% over the best treatment. Highest net return and net return per rupee invested was obtained from the application of lower dose (717.5 g/ha) of new herbicide combination product while weed free treatment gave lowest net return per rupee invested. No phytotoxic effect of any of the herbicides (penoxsulam, bispyribac sodium, butachlor and penoxsulam + butachlor) was observed on transplanted rice.

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Assessment of integrated weed management in direct-seeded rice under rainfed conditions

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Rice is the staple food of the people of the eastern and southern parts of the country. Direct-seeded culture has become increasingly important in rice cultivation due to scarcity of rural labour and higher water requirement and production costs involved in transplanted rice. Direct-seeded rice needs only 34% of total labour requirement and saves 27% of the total cost of the transplanted crop. Irrespective of the method of rice establishment, weeds are a major impediment to rice production through their ability to compete for resources and their impact on product quality. Weeds are responsible for heavy rice yield losses, to the extent of complete crop loss under extreme conditions. Out of losses due to various biotic stresses, weeds are known to account for nearly one third. Weed competition would be less severe under transplanting than those under direct seeding. Uncontrolled weeds reduced the grain yield by 75.8, 70.6 and 62.6% under dry-seeded rice, wet-seeded rice and transplanted rice, respectively. On-farm trials were conducted in Rewa district of Madhya Pradesh under close supervision of Krishi Vigyan Kendra. Total 21 on-farm trials (OFT) under real farming situations were conducted during *Kharif* seasons of 2016-17 and 2017-18 (two consecutive years) at five different villages namely; Khokham, Purena, Semarikala, Reethi and Majhiayar; respectively under Krishi Vigyan Kendra operational area. The area under each trial was 0.2 ha. The treatment comprised of T_1- farmer's practice, T_2- application of pendimethalin at 1000 g/ha at 0-3 DAS, T_3- T_2 + application of bispyribac sodium salt 25 g/ha at 20-25 DAS. In this study, we evaluated the effective weed management practices for direct-seeded rice on yield and yield attributing characters of rice under rainfed conditions. Two years mean result of on farm testing (OFT) showed a greater impact on farmers' economy due to significant increase in crop yield up to 3.61 t/ha under T_3 followed by 2.91 t/ha under T_2 as compared to 2.4 t/ha in FP (T_1). It was 49.5% higher under T_3 followed by 20.4% under T_2 than T_1. Weed intensity was found highest under T_1 (332/m^2) followed by T_2 (132/m^2) and it was lowest under T_3 (23/m^2). The net profit under T_3 was ` 35,180/ha followed by ` 25,929/ha under T_2 as compared to ` 18,853/ha under T_1. Benefit cost ratio was 2.60 under T_3 followed by 2.28 under T_2, while it was 2.02 under T_1. The result of on-farm trials convincingly brought out that the yield of rice could be increased with the intervention on weed management in direct-seeded rice in the Rewa district.

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Impact of farmers field demonstration program of integrated weed management in rice

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Rice is grown under various agro-climatic conditions and the yield losses due to weeds alone is around 37%. More than 30 genera of weeds infest the rice fields at different crop growth stages. With the objective of reducing cost of cultivation and increasing economic benefit by implementing Integrated Weed Management (IWM) package *i.e.*, Judicious combination of various crop management practices *viz.*, summer ploughing and non selective herbicide application, selection of suitable newly released mid-early high yielding variety, recommended seed rate, use of pre-emergence followed by post-emergence herbicide use, top dressing the required and recommended quantity of nitrogen using leaf color chart have been found quite effective and economical; was implemented through Krishi Vigyan Kendras and Department of Agriculture in the villages of Puppalaguda, Ranga Reddy district,; Nagapur and Rajampet, Medak district; Amrad, Madanpalle Thanda, Banapoor, Nizamabad district of Telangana State, India. Some of the prevailing weeds in these areas are of national significance, while others are of regional significance *e.g.*, weeds like *Echinochloa colona, E. crassipes, Cyperus* difformis, *Cyperus irea, C.rotundus, Paspalum disticum, Panicum* spp., *Eclipta alba, Ammania baccifera, Marselia quadrifoliata*. Manual weeding has been commonly used in rice fields to minimise yield losses from weed competition. However in context of declining timely labour availability, cost of labour *etc.*, safe and effective integrated weed management package was developed, recommended , demonstrated and implemented in the farmers fields. The tailer made package included mid early High Yielding Variety DRR Dhan44 of IIRR, Hyderabad and recommended seed rate of 30 kg/ha instead of prevailing practice of high seed rate (double than recommended) 60-70 kg/ha for robust nursery; the pre-sowing herbicide application of glyphosate 15 days before planting; *application of oxadiargyl at 7 days after planting (DAT) followed by chlorimuronethyl + metsulfuronmethyl at 25 DAT in some fields; application of bispyribac sodium at 30-40 DAT in some fields depending on the weed flora and intensity, top dressing of nitrogen based on leaf color chart of IIRR, Hyderabad (saving of 25-30 kg nitrogen); need based application of plant protection chemicals instead of blanket application. By implementing the above mentioned management technologies the farmers achieved monetary benefit mainly by reducing the input cost which has reflected in higher yields except two farmers who has water problem. Adoption of Integrated Weed Management helped the farmers to achieve monetary advantage which works out to the yield advantage of 3 to 30%. Energy dynamics also showed higher energy output and energy efficiency in IWM implemented rice farms. In order to accelerate the rate of adoption, a farmer's day was conducted and more than hundred farmers of nearby villages witnessed the positive effect of adopted IWM interventions in the farmer fields. The beneficiary farmers shared the positive experiences of IWM interventions with the other farmers.

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Weed suppression ability of scented rice varieties, weed dynamics and seed bank studies in direct-seeded paddy at Raipur (Chhattisgarh)

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Seed bank /seed pool estimation is an important evaluation tool to predict the possibility of future weed infestation in nascent native plant diversity. Hence, the seed emergence techniques used in soil of different depth of layers in soil of the field portrays the approximate seed volume in the soil. Thus, the study was undertaken in direct seeded paddy field in rain fed lowland conditions in *Kharif* season at instructional farm of IGKV using five scented rice varieties *i.e.*, Badshahbhog, Pusabasmati, Gopalbhog, Vasumati and Dubraj in split plot design at NPK levels 100:80:60 kg/ha. Seed emergence was significantly higher in upper layer of soil 90-15 cm depth and contributed maximum share to the seed bank composition and ranges 41.79 seeds in 0-5 cm and decreased gradually and observed 36.30 from 5-10 cm and 28.28 from 10-15 cm depth of soil. However, the deep layers 15-20 cm possessed minimum number of weed seeds *i.e.*, 18.61 in per 2.0 kg of soil. The number of BLW were slightly higher than grasses in rain fed lowland conditions. Maximum weed control efficiency 73.10% was observed in variety Gopalbhog, followed by Pusabasmati (69.81%), Badshahbhog (65.70%) and Vasumati (64.36%). Minimum weed control efficiency was observed in variety Dubraj (61.10%).

However, in another studies of direct seeded rain fed lowland conditions taking twenty one rice genotypes belonging to early, mid early (medium) and long duration. *Croton banplandianum*, *Borreria hipida*, *Cyperus* spp. and *E. colonum* were dominated weed species. Whereas, *Isehaemum rugosum*, and *Aeschynomene indica* were the minor weed species. Genotype R-1099-25-26-1-1 have high weed tolerance and at high population of weed species it have high HI. While, genotype Denteshwari have higher number of weeds and low weed control efficiency. When leaf and root extract of these genotypes was applied to study the germination behavior of *Echinochloa colonum* it was observed that the genotype Denteshwari permitted high weed population and densities its extract also promoted germination percentage and less adverse effect on seedling growth and seedling dry biomass of *E. colonum* as compared to other experimental genotypes. Maximum reduction in germination percentage and more adverse effect on seedling growth in *E. colonum* was observed in rice genotype r-548-89-6 and followed by R-1072-36 and Dubraj. Roor extract of Dubraj also have decreased the germination percent of *E. colonum*.

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Weed flora and its population in different rice based cropping system under assured irrigation condition

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Rice-based cropping system can be described as mix of farming practices that comprises of rice as the major crop followed by subsequent cultivation of other crops. Rice-based cropping system is a major cropping system practiced in India, which include the rotation of crops involving cereals, pulses, oilseeds, green manures, vegetable, *etc*. Various rice-based cropping systems have been reported from different parts of India ranging from rice-rice to rice followed by different cereals, pulses, oilseeds, vegetables and fiber crops. Rice-based cropping systems may include lowland and upland crops. Weed competition is a major constraint in all the rice production systems in India. The phenomenon of shift in kind and density of weed species is the result of manipulation of environmental factors, crop rotation and weed control practices. The continuous adoption of the same crop rotation coupled with the use of particular weed management practices lead to shift in weed flora in time.

The experiment was carried out at Research and Instructional Farm of Indira Gandhi KrishiVishwavidyalaya, Raipur during *Kharif*, *Rabi*, and summer season. The soil of the experimental field was silty clay in texture with medium in nitrogen, phosphorus and potassium contents. The treatments consisted of seven cropping sequences *viz*. T_1: rice-wheat-fallow, T_2: rice-mustard-green manure, T_3: rice-coriander (green leaf)-mung, T_4: rice-pea (table)-maize (F), T_5: rice-brinjal-GM, T_6: rice-onion-GM and T_7: rice-potato-cowpea. The experiment conducted in approved design from AICRP project *i.e*. Balanced Incomplete Block Design (BIBD) with four sets in plot size of 70 m^2 each. The All crops were raised as per the recommended package of practice.

The prominent weed species observed in the experimental field were *Echionochloa colona*, *Cynodon dactylon, Cyperus* sp., *Eleusine indica, Anagalish arvensis, Chenopodium album, Phyllanthusniruri, Parthenium hysterophorus, Meliotus alba, Solanum nigram, Vicia hirsute, Degetaria sanguinalis.* Among the predominate weed species are *Melilotus* spp*., Chenopodium album* and *Echinochloa colona* under various *Rabi* crops.

In all the above mentioned weed flora *Meliotus* spp. (40.12 and 39.34%) was the most predominate weed of total weeds which have 40.12 and 39.34% population flora at 30 and 60 DAS, respectively followed by *Chenopodium album* (33.60 and 39.34%) *Echinochloa colona* (16.27-13.28%), respectively at 30 and 60 DAS. It is obvious from the table that the coriander crop highly (188.46/m^2 and 215.14/m^2) infested by weed at 30 and 60 DAS respectively, followed by mustard (176.54/m^2) at 30 DAS. The lowest weed population in potato crop (46.68/m^2) followed by onion (56.69/m^2) at 30 DAS, while the lowest weed infestation at 60 DAS under rice-potato-cowpea (80.14) followed by rice-onion-GM (80.71) cropping sequence.These might be due to the growth behavior of coriander and mustard. The initial growth of mustard and coriander were slow as compared to reset of *Rabi* crop. The mustard crop allowed fast growth being wider spaced crop. The weed population was lower in potato and onion because of intercultural operation as per schedule restrict the growth of weeds.

The highest weed dry matter production was observed in coriander (9.0 g/m^2) at 30 and 60 DAS respectively because of slow growth of coriander leaves in early growth stage as compared to other crop so weeds maximum light, water and nutrient for quick growth . The lowest weed dry matter production by potato (2.56/m^2) and (73.80/m^2) at 30 and 60 DAS, due to suppression and mortality of weeds during interculture operation.

Among different cropping sequences evaluated T_7 (rice-potato-cowpea) system was identified to be most productive with rice-equivalent yield of (27.04 t/ha/year). The next best sequence was T_5 (rice-brinjal-GM) with (21.32 t/ha/year) rice- equivalent yield. T_7 (rice-potato-cowpea) cropping sequences gave significantly higher production efficiency (83.97kg/ha /day), profitability (Rs 320.36/ha /day) and relative economic efficiency and (199.29 per cent). Net return of higher ` 116929/ha /year was obtained under T_7 (rice-potato-cowpea) but the maximum B: C ratio was recorded under (2.65) T_5 (rice-brinjal-GM) cropping sequences due to huge cost involved for purchase of potato seed.

Theme 7

Weed management in cereals-based cropping system

Effect of tillage and weed management on weeds and system productivity of soybean-wheat-greengram system under conservation agriculture

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Conservation agriculture (CA) is a new paradism in the twenty-first century and has gained importance to make farming more profitable by cutting down the variable cost and enhancing resource-use efficiency and soil properties. However, weed management is a major issue for success of CA-based cropping systems. In view of this, an experiment was carried out at the ICAR-Directorate of Weed Research, Jabalpur, Madhya Pradesh during 2013-14 and 2014-15. The field experiment consisted of 15 treatment combinations, comprising of five tillage practices as main-plot treatments, *viz.* conventional tillage in soybean-conventional tillage in wheat, conventional tillage in soybean-zero tillage in wheat-zero tillage in greengram, zero tillage with preceding crop residue in soybean-zero tillage in wheat-zero tillage with preceding crop residue in greengram, zero tillage in soybean-zero tillage with preceding crop residue in wheat-zero tillage with preceding crop residue in greengram, zero tillage with preceding crop residue in soybean-zero tillage with preceding crop residue in wheat-zero tillage with preceding crop residue in greengram and three weed management as sub plot treatments, *viz.* weedy check in all crops, pendimethalin 750 g/ha *fb* imazethapyr 100 g/ha in soybean-mesosulfuron 12 g/ha + iodosulfuron 2.4 g/ha in wheat-pendimethalin 750 g/ha in greengram, metribuzin 500 g/ha + 1 HW at 25 DAS in soybean- metsulfuron 4 g/ha + clodinofop 60 g/ha in wheat-pendimethalin 750 g/ha + 1 HW in greengram, were laid out in split plot design on fixed site and replicated thrice. Results indicated that the total density of weeds was reduced to minimum when zero tillage was done in presence of residues of preceding crop in all component crops. But chemical weed control with pendimethalin 750 g/ha *fb* imazethapyr 100 g/ha in soybean- mesosulfuron 12 g/ha + iodosulfuron 2.4 g/ha in wheat-pendimethalin 750 g/ha in greengram caused effective control of total weeds and found effective in curtailing the population including dry weight of dominant grassy and dicot weeds. However, conventional tillage in both soybean and wheat crops had minimum system productivity in terms of soybean equivalents yields, which was identically increased when conventional tillage was done in soybean, zero tillage in wheat and greengram being maximum in plots receiving zero tillage in presence of residues of preceding crop in all component crops. Both herbicidal treatments *i.e.* metribuzin 500 g/ ha + 1 HW insoybean, metsulfuron + clodinafop 4+60 g/ha in wheat and pendimethalin 750 g/ha+ 1 HW in green gram and pendimethalin 750 g/ha *fb* imazethapyr 100 g/ha in soybean, ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha in wheat and pre-emergence application of pendimethalin 750 g/ha in greengram were found superior as both attained higher system productivity compared to weedy check plots where weeds were not controlled throughout the crop growing season.

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Weed dynamics as influenced by long-term application of fertilizers in maize – wheat cropping system

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Weeds are the serious constraints in maize-wheat cropping system. Studying the weed dynamics is helpful to understand the dominance or presence/absence of a particular species in a crop/cropping system, devise means and ways to reduce their population, find out ways to delay or avoid the development of resistance by them against a herbicide, identify suitable crops for crop rotation/ diversification and modify agronomic practices in favour of healthy crop growth. An appraisal of weed flora associated in a long – term experiment on fertilizers in maize-wheat cropping system (AICRP on LTFE) was made during 2017-18.

In the experimental plot twelve weed species were found growing after the harvest of wheat (May end). *Digitaria* was the most dominating weed constituting 65% of the total weed flora. This was followed by *Polygonium plebegium* (9%), *Plantago lanceolata* (7%), wild dhania, *Scandix pecten veneris* L. (5%) and *Gallinsoga parviflora* (4.6%). Long-term repetitive application of same nutrients year after year brings about conditions conducive for the growth of specific weed flora. That is why in the present investigation fertility treatments brought about significant variation in the count of *Digitaria sanguinalis*, *Plantago lanceolata* and *Gallinsoga parviflora* and thereby grasses and broad-leaved weeds together. Population of *Digitaria sanguinalis* was significantly low in T_1 (50% NPK), T_8 (100% NPK + FYM), T_{10} (100% NPK + lime) and T_{12} (Natural farming) treatments. Trend in the count of grassy weeds was similar to the count of *Digitaria sanguinalis*. Population of *Plantago lanceolata* was significantly higher in natural farming treatment being comparable to T_1. T_2 (100% NPK), T_3 (150% NPK), T_7 (100% N) and T_9 (100% NPK +S) being at par with T_4-T_6 (100% NPK + handweeding, HW; 100% NPK + Zn; 100% NP) had significantly lower population of *Plantago lanceolata* over the other fertility treatments. Population of *Gallinsoga parviflora* was significantly lower in T_7 (100% N) being at par with T_2-T_3, T_5-T_6 and T_{11}-T_{12}. Its population was significantly higher in T_8 where FYM was applied. However, T_1, T_4 and T_{10} were comparable to T_8 in influencing the population of *Gallinsoga parviflora*. T_7 remaining at par with T_2 and T_9 had significantly lower population of broad-leaved weeds as compared to other treatments. T_{12} being at par with T_1, T_6, T_8, T_{10} and T_{11} had significantly higher population of broad-leaved weeds.

Dgitaria sanguinalis was the most abundant weed in most of the treatments (T_2-T_7, T_9, T_{11}, T_{12}) thereby on the overall basis. *Polygonum plebebejium* was the most abundant weed in T_1 and T_{10}. Wild dhania was most abundant in T_8.

Digitaria sanguinalis was most important weed having highest SDR in all the treatments except T_{12} (Natural farming treatment). In the natural farming treatment *Plantago lanceolata* ranked first in importance followed by *Digitaria sanguinalis* and *Artimissia* sp. *Plantago lanceolata* was next only after *Digitaria* in T_1. Irrespective of the treatment *Digitaria sanguinalis* ranked first in importance followed by *Polygonum plebigium*, *Plantago lanceolata* and *Gallinsoga parvoflora*. The comprehensive appraisal of the associated weed flora will be presented.

Population structure of invaded species in wheat crop under agroforestry system in central Chhattisgarh

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Agriculture crops always have competition with growing weeds which were invaded by several means and create potentially interaction to affect the performance and yield of the crops. In *Agroforestry* systems the biotic and abiotic stresses cause reduction in performance of crop to various extents depending upon the nature and intensity of infestation

This study aimed at analyzing the effect of canopy of 6 yrs old *Eucalyptus tereticornis* and *Dalbergia sissoo* grown at 5 x 5 m spacing, on distribution pattern of allian species as compare to open field during winter season wheat crop in humid tropic climate of Central Chhattisgarh. The height growth of trees after 6 yrs was more in *E. tereticornis* (7.4 m) than *D. sissoo* (7.1 m) with diameter at breast height of 6.5 and 12.8 cm, respectively, but the crown width expansion was more in *D. sissoo* (3.9 m) than *E. tereticornis* (2.1 m). Thus photosynthetically active radiation (PAR) available to the growing wheat crop was 69 and 49.3% intercepted by crown's foliage of *D. sissoo* and *E. tereticornis* respectively. Plant population of wheat crop was recorded maximum in open plot (289/m^2) followed by crop under *D. sissoo* (188/m^2) and *E. tereticornis* (168/m^2) with 118.6, 126.2 and 130.1 cm crop height respectively. But the formation of tillers per plant was in order of control (4.1), *E. tereticornis* (3.6) and *D. sissoo* (3.3).

The phytosociological indices of invaded alien species accounted total 14 species which were 8,7 and 6 *D. sissoo*, *E. tereticornis* and open field respectively with 14.3% similarity index of common species *viz; Euphorbia hirta* and *Phyllanthus niruri*. The invaded alien species were accounted as 5 grasses, 3 legumes and 6 others forbs and these were *Alternanthera ficoidea, Alysicarpus* sp, *Cynodon dactylon, Cyperus rotundus, Dicanthium annulatum, Echinochloa* sp, *Eragrostis* sp, *Euphorbia hirta, Glycin max, Parthenium hysterophorus, Paspalum conjugatum, Phyllanthus niruri, Themeda quadriwalvis* and *Trifolium* sp. The population density of invaded alien species were found in order of open > *E. tereticornis* > *D. sissoo* and it was accordance to availability of sun light. Thus the level of dominance was found more in the open field (0.38) as compared to *E. tereticornis* (0.25) and *D. sissoo* (0.16) with diversity index of 0.58, 0.71 and 0.83 respectively. The control of invade species in agroforestry environments was much complicated because more than one crop are grown at the same time and space, hence control measures are needed to recognize according to each crop *viz;* trees, shrubs and herbaceous so that effects of one control method could not be reflected on other crops, here the removal of invaded species at early stage by mechanically was more effective and safe to each crop in agroforestry system as compared to sole-cropping system.

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Conservation agriculture versus conventional tillage: Impact of weed management with right dose of fertilizer on wheat yield

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Wheat is an important crop worldwide and in India, it is the second most important staple food after rice. Its production increased from a meagre 11.0 million tonnes during 1960-61 to 97.11 million tonnes during 2017-18 (Directorate of Economics and Statistics, Ministry of Agriculture) due to the adoption of short duration high yielding varieties along with increased fertilizers, irrigation and herbicides used. The high nutrient and water requirements along with less competitive nature of these high yielding dwarf varieties have provided the conductive environment for increased weed infestation. Weeds account for about one third of total losses caused by all pests. Weed is one of the most important factor which effect crop growth and yield. Potential yield losses in wheat have been reported as 10-60 per cent due to weeds (Rao *et al.* 2014). Therefore, for sustaining food grain production to feed every increasing population and ensuring food security, for this effective weed management is very essential. Conservation agriculture work in three principal like minimum tillage, residue retention and crop rotation also herbicide use has been an extremely important component of weed management in conservation agriculture (CA) systems for achieving higher productivity. The goal of this paper is to analyse the comparative study of both agricultural farming; conservation and conventional tillage as well as determine which of these technologies encourages yield. This study conducted two districts namely Mandla (four villages) and Narsinghpur (three villages) of Madhya Pradesh. The primary data collected from 32 farmers purposively from seven villages of two districts of Madhya Pradesh, where carried out the On-farm Research trails cum demonstration on weed management under conservation agriculture (CA) by ICAR-Directorate of Weed Research, Jabalpur during 2016-17. The data were analyzed using descriptive statistics to estimate cost of cultivation. Result shows that, the overall average wheat yield recorded was 63% higher under CA compared with conventional practices by applied the herbicides (clodinafop + metsulfuron at 60 + 4 g/ha) with application of recommended dose (RFD) 120:60:40-N,P_2O_5, K_2O kg/ha under CA at 30 day after sowing (DAS) resulted in the lowest weed density and biomass. Under the CA overall total cost was (` 19625/ha) lower as compared to Conservation agriculture (` 27287.5/ha) recorded. The overall average gross return and net return of wheat was recorded (` 72858 and ` 53233/ha) higher under the CA compared to conventional tillage (` 52800 and ` 25512.5/ha). Benefit cost ratio was recorded as 3.74 in CA and 1.94 in conventional tillage. As compared to farmers practices/conventional tillage used the higher seed rate, unbalanced fertilizer dose, more irrigation and without proper weed management.

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Influence of rice crop establishment methods and weed management practices on rice-maize cropping system

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A field experiment was conducted to study the influence of crop establishment methods and weed management practices of rice on growth and productivity of zero-till maize during 2011-12 and 2012-13. The experiment was laid out in split plot design with three replications. The treatments consisted of three establishment methods, direct seeded rice, SRI and transplanting as main plots; weed management practices in rice, bensulfuron methyl 60 g + pretilachlor 600 g/ha *fb* mechanical weeding at 30 DAS/T, bispyribac sodium 25 g/ha, farmer's practice (hand weeding twice at 20 and 40 DAS in direct seeded rice and transplanted rice, conoweeding thrice from 20 DAT with 10 days interval in SRI) and weedy check as sub-plots and weed management practices in maize (during *Rabi*) *viz.* weedy check, atrazine 1.0 kg/ha, atrazine 1.0 kg/ha *fb* topramezone 30 g/ha and hand weeding twice at 20 and 40 DAS as sub-sub plots. Numbers of grains per cob, grain weight per cob and grain yield were found to be significantly higher when the maize was grown after transplanting method of rice and which was significantly superior over other two methods of establishment. The highest grain yield of maize was due to higher availability of nutrients, lower weed dry matter which resulted in higher dry matter accumulation and higher yield attributes. Among weed management practices in rice, farmer's practice of weeding resulted in higher yield and yield attributes of maize and which was on par with bensulfuron methyl 60 g + pretilachlor 600 g/ha *fb* mechanical weeding at 30 DAS/T. The treatments imposed on rice showed similar effect on weed dry matter and yield in both rice and succeeding maize. In maize, hand weeding twice at 20 and 40 DAS resulted in significantly lower weed density and dry matter and recorded higher yield attributes and yield of maize compared to other weed management practices. It can be concluded that transplanting method of establishment and application of bensulfuron methyl 60 g + pretilachlor 600 g/ha followed by mechanical weeding at 30 DAS/T in rice, application of atrazine 1.0 kg/ha followed by topramezone 30 g/ha in maize is more beneficial to get higher productivity and profitability of the rice-maize system.

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Management broad-leaf weeds in wheat through herbicides

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Wheat (*Triticum aestivum* L.) is an important cereal which is consumed as direct source of food for human beings in the world. India is the second largest wheat producer after China in the world. Significant reduction in wheat grain yield due to presence of different weeds has been reported by researchers across the globe and different wheat varieties. Although wheat is being adversely affected by the complex weed flora in the world but under certain conditions broad-leaf (*Chenopodium album, Malva neglecta, Melilotus indica, Coronopus didymus, Anagallis arvensis* and *Vicia sativa*) can cause upto 60% yield reduction. To address the sustainable weed management in wheat, a field experiment was conducted to assess the possibility of broad-leaf weed management in wheat using different herbicides during 2016-17 and 2017-18. The eleven weed control treatments namely halauxifen-methyl ester + florasulam 40.85% WG + surfactant polyglycol 26-2 N (12.76 g + 750 ml/ha), metsulfuron-methyl 20 WG + surfactant (4.0 g + 625 ml/ha), carfentrazone 40 DF (20.0 g/ha), 2,4-D Na 80 WP (500 g/ha), 2,4-D E 38 EC (500 g/ha), metsulfuron + carfentrazone + surfactant (4.0 g + 20 g + 625 ml/ha), 2,4-D Na + carfentrazone (400 + 20 g/ha), 2,4-D E + carfentrazone (400 + 20 g/ha), halauxifen-methyl + florasulam + carfentrazone + surfactant (10.21 + 20 g + 750 ml/ha), weedy check and weed free were replicated thrice in RBD. These herbicides were applied at 30-35 days after sowing. The soil was low in available N and P. The data pertaining to weed density was recorded by quadrat (1 × 1 m) 60 days after herbicide application and dry matter was recorded by drying in oven. Lower weed population was recorded where tank mix of carfentrazone with metsulfuron (2.56 and 2.31/m^2), 2,4-D ester (2.65, 2.69/m^2), 2,4-D Na (2.85, 2.66/m^2), halauxifen + florasulam + carfentrazone + surfactant (3.04, 3.96/m^2) were applied as compared to sole application of these herbicides. Similar trend was observed for weed dry matter accumulation 90 days after herbicide application and also weed control efficiency. The highest grain yield was recorded in metsulfuron + carfentrazone + surfactant treatment which was significantly higher than weedy check treatment. In 2016-17, metsulfuron + carfentrazone + surfactant treatment reorded grain yield similar to all herbicidal treatments. However, in 2017-18, this treatment recorded significantly higher grain yield than metsulfuron + surfactant, 2,4-D Na and 2,4-D E. In the second year of experimentation *Malva neglecta* weed was the main broad-leaf weed.

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Weed management in maize using different pre- and post-emergence herbicides

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An agronomic investigation entitled "Weed management in maize (*Zea mays* L.) using different pre- and post- emergence herbicides" was carried out at Agronomy Farm, Nagpur during 2015-16 to evaluate the comparative efficiency of herbicides with different doses. The experiment comprising of eleven weed management treatments was conducted in a randomized block design with three replications. The results revealed that highest weed control efficiency of 100% and lowest monocot, dicot and total weed count was recorded under weed free treatment with highest mean seed yield (5.91 t/ha) and straw yield (8.89 t/ha) and also highest in other yield attributes *viz*. cob bearing/plant (1.16), number of grain/cob (477.36), grain weight/ cob (80.89 g) and test weight (27.39 g). Among different herbicidal treatments involving pre- emergence application ofoxydiargyl (60, 75, 90 g/ha) and post-emergence application of metsulfuron-methyl (4, 5, 6 g/ha) at 15 DAS, and halosulfuron-methyl (100, 125, 150 g/ha) at 15 DAS were also found equally effective. Among different herbicidal treatments metsulfuron-methyl (4 g/ha) 15 DAS recorded lowest dry weight of weeds (5.92 g) and higher weed control efficiency (71.30%) than remaining tested herbicides. The growth attributes *viz.* plant height (176.72 cm), dry weight of plant (162.86 g) and yield attributes, *viz.* cob bearing/plant (1.14), number of grain/cob (427.50), weight of grain/cob (75.99 g) and test weight (26.28 g) were highest in metsulfuron-methyl 4 g/ha 15 DAS as post-emergence. Among herbicides, the highest grain yield (5.67 t/ha), straw yield (8.51 t/ha), maximum net return (` 72123/ha) and highest B:C ratio (4.67) were also obtained with the application of metsulfuron-methyl 4 g/ha 15 DAS.

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Integrated weed management in wheat

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A field investigation entitled "Integrated weed management in wheat (*Triticum aestivum* L.)" was conducted during *Rabi* season of 2012-13 at Agronomy Farm, College of Agriculture, Pune (Maharashtra). The experiment with nine treatments and three replications was laid down in randomized block design. The soil of experimental field was clay loam in texture, low in available nitrogen (163.00 kg/ha), medium in available phosphorus (19.89 kg/ha) and high in potassium (475.78 kg/ha) and was alkaline in reaction (pH 7.54). A full dose of phosphorus and potassium was applied as a basal application. The nitrogen was applied in two splits, half at sowing and half at 21 DAS. Wheat variety '*Godavari*' (NIDW-295) was sown using 125 kg seed/ha at spacing of 22.5 cm between the lines. According to the treatment, pendimethalin was applied after sowing but before emergence of crop and post-emergence herbicides were sprayed at 18 DAS through knapsack sprayer with flat fan nozzle using 500 litres of water/ha. The result indicated that pre-emergence application of pendimethalin 1.0 kg/ha + hoeing at 30 DAS recorded lower monocot and dicot weed population over rest of the weed management treatments. The dominant weed flora in experimental plots comprised *Brachiaria eruciformis*, *Cynodon dactylon*, *Cyperus rotundus*, *Parthenium hysterophorus*, *Portulaca oleracea*, *Digera arvensis*, *Amaranthus viridis* and *Convolvulus arvensis*. Amongst the weed management treatments, significantly the lowest weed dry matter (5.10 g/m^2), higher weed control efficiency and weed index (5.69) were recorded with pre-emergence application of pendimethalin 1.0 kg/ha + hoeing at 30 DAS. Statistically higher values of yield attributes, grain yield (3.71 t/ha) and straw yield (4.78 t/ha) were obtained from the treatment of pendimethalin 1.0 kg/ha as pre-emergence + hoeing at 30 DAS due to effective weed control of both grassy as well as non grassy weeds and higher weed control efficiency. Minimum values of yield attributes and yield were registered with weedy check. Significantly maximum gross monetary returns of ` 101,561/ha was obtained in weed free check. However, significantly more net returns of ` 58,166/ha and maximum benefit cost ratio of 2.55 was recorded with application of pendimethalin 1.0 kg/ha as pre- emergence + hoeing at 30 DAS, but it was at par with metsulfuron-methyl 3 g/ha PoE at 18 DAS + hoeing at 30 DAS, metribuzin 131 g/ha PoE at 18 DAS + hoeing at 30 DAS, 2, 4-D 563 g /ha PoE at 18 DAS + hoeing at 30 DAS, metsulfuron-methyl 4 g/ha PoE at 18 DAS and metribuzin 175 g /ha PoE at 18 DAS. Thus, by considering the economics and productivity of wheat, the most suitable integrated weed management practice would be application of pendimethalin 1.0 kg/ha as pre-emergence + hoeing at 30 DAS.

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Effect of post-emergence herbicides on growth, yield and economics of late sown wheat

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A field experiment was carried out during *Rabi* season of 2014 in medium black soil at Post Graduate Research Farm, College of Agriculture, Dhule, Maharashtra, to study the effect of post- emergence herbicides on growth, yield and economics of late sown wheat (*Triticum aestivum*). The soil of the experimental field was clayey in texture with low in available nitrogen (194.43 kg/ha), medium in phosphorus (16.64 kg/ha) and very high in available potassium (383.00 kg/ha). The experiment was laid out in randomized block design with three replications. There were eight treatments *viz.* weedy check, weed free check, clodinafop (60 g/ha), sulfosulfuron (25 g/ha), metsulfuron-methyl (4 g/ha), metribuzin (100 g/ha), clodinafop + metsulfuron-methyl (60+4 g/ha), sulfosulfuron + metsulfuron-methyl (25+4 g/ha). Among herbicidal treatments, tank-mix application of sulfosulfuron + metsulfuron-methyl (25+4 g/ha) (PoE) recorded maximum weed control efficiency and the lowest weed index and which was at par with clodinafop + metsulfuron-methyl (60+4 g/ha) (PoE). All the growth contributing characters of wheat *viz.* plant height, number of tillers, and total dry matter accumulation were significantly higher in weed free check. This was followed by application of sulfosulfuron + metsulfuron-methyl (25+4 g/ha) (PoE) however, it was at par with clodinafop + metsulfuron-methyl (60+4 g/ha (PoE). The significant effect on growth character of plant was noticed due to different treatments which resulted in enhanced yield contributing character *viz.* length of earhead, number of earheads/unit area, number of grains/ spike and test weight. The highest grain and straw yield of wheat (4.75 t/ha and 5.97 t/ha, respectively) were recorded in weed free check than rest of the treatments. This was followed by application of tank-mix herbicide *i.e.* mulfosulfuron + metsulfuron-methyl (25 + 4 g/ha) (PoE) (4.30 t/ha and 5.42 t/ha), which was found at par with application of clodinafop + metsulfuron-methyl (60 + 4 g/ha), (4.11 t/ha and 5.07 t/ha). This may be due positive effect of herbicides mixture in controlling complex weed flora as compared to its alone application. The gross and net monetary returns were found maximum (` 91980 and 54891/ha, respectively) in weed free check treatment followed by tank-mix application of sulfosulfuron + metsulfuron-methyl (25 + 4/ha) (` 79706 and 50867/ha, respectively) than rest of the treatments. Benefit cost ratio was maximum in tank-mix application of sulfosulfuron + metsulfuron-methyl (25+4 g/ha) (2.91) followed by clodinafop + metsulfuron-methyl (60+4 g/ha) (2.76). However, the gross and net monetary returns were maximum under weed free check but the lower B-C ratio as compared to tank-mix application of sulfosulfuron + metsulfuron-methyl (25+4 g/ha) due to higher cost for weeding.

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Efficacy of pre- and post-emergence herbicides in wheat

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Nowadays weed is one of the major barriers responsible for low productivity of wheat. Cultivation of semi-dwarf input responsive wheat cultivars with slow initial growth provide favourable environment for weeds. Wheat field is generally infested from both monocot and dicot weeds. Chemical weed control is a preferred practice due to scarce and costly labour as well as lesser feasibility of mechanical or manual weeding especially in broadcost wheat. To control diverse weed flora, application of two or more herbicides is advantageous to control broad-spectrum weed flora. Hence, this trial was done to assess efficacy of different pre- and post-emergence herbicides in wheat.

The field investigation entitled "Efficacy of pre- and post-emergence herbicides in wheat" was carried out at AICRP on Weed Management field, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the *Rabi* season of 2016-17.The investigation was carried out to study the relative efficacy of herbicides on weed control in wheat as well as to study its effect on growth and yield of wheat. The experiment was laid out in randomized block design with twelve treatments replicated thrice. The treatments comprised of pendimethalin at 1 kg/ha, metribuzin at 0.21 kg/ha, sulfosulfuron at 0.025 kg/ha, clodinafop at 0.06 kg/ha, pendamethalin + metribuzin at 1 + 0.175 kg/ha, pendimethalin *fb* sulfosulfuron at 1 + 0.018 kg/ha, sulfosulfuron + metsulfuron at 0.3 + 0.002 kg/ha, pinoxaden + metsulfuron at 0.6 + 0.004 kg/ha, mesosulfuron + iodosulfuron at 0.012 + 0.0024 kg/ha, clodinafop + metsulfuron at 0.06 + 0.004 kg/ha, 2 hand weeding (30 and 60 DAS) and unweeded control treatment. In the experimental field, predominant weed flora were *Amaranthus polygamus, Euphorbia hirta, Euphorbia geniculata, Phyllanthus niruri, Parthenium hysterophorus, Argemone mexicana, Amaranthus viridis, Chenopodium album, Melilotus indica, Portulaca oleracae, Alternanathera triandra, Digitaria sanguinalis, Dinebra retroflexa,* among the dicot weed and *Cyperus rotundus, Cynodon dactylon, Dinebra arabica, Commelina benghalensis* among the monocot.

The results revealed that, among the various treatments under study, two hand weeding at 30 and 60 DAS recorded significantly higher values of major growth parameters whereas, among the herbicidal treatments, the maximum growth and yield attributes were recorded with treatment pendimethalin *fb* sulfosulfuron at 1 + 0.018 kg/ha. Among the post-emergence herbicides, reduction in weed population, weed dry matter, higher weed control efficiency and lowest weed index was found in pendimethalin *fb* sulfosulfuron at 1 + 0.018 kg/ha PoE 35 DAS. Two hand weeding registered highest grain yield (4.59 t/ha) which was comparable with pendimethalin *fb* sulfosulfuron at 1 + 0.018 kg/ha PoE 35 DAS (4.49 t/ha). Weedy check recorded lowest grain yield (2.32 t/ha). Though gross monetary returns (` 82,292/ha) was maximum in two hand weeding but net monetary returns was maximum in clodinafop + metsulfuron at 0.06 + 0.004 kg/ha (` 56,120/ha) and B:C ratio (3.20) due to higher labour cost of weeding in hand weeding treatments, hence, the treatment clodinafop + metsulfuron at 0.06 + 0.004 kg/ha proceed superior in economic returns than rest of the treatments.

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Brown manuring in maize: An effective approach for weed management

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Maize (*Zea mays* L.), the third most important cereal crop after rice and wheat, is cultivated in an area of 9.5 million hectares with annual production of 24.5 million tonnes in India. It serves mankind through various means, *viz.* food, feed, and fodder and basic raw materials for several industrial products. However, the productivity of maize is low due to several biotic and abiotic stresses. Weeds are one of the major biotic constraints, which can cause up to 40% yield reduction in maize. Herbicides can suppress weed growth, but continuous use of herbicides of similar group (s) can lead to development of resistance in weeds over the years. Less herbicide-driven and climate-resilient integrated weed management (IWM) is need of the hour for sustainable maize production under changing climate. Brown manuring (BM) is a practice of growing *Sesbania*/*Crotalaria* as co-culture with a crop for a short period of 25-30 days, and then, killing by the application of post-emergence herbicides selective to crop of prime interest. BM offers multiple benefits such as weed suppression and some ecosystem services including enhancement of soil C and N reserves. Therefore, to investigate the effects of brown manuring on weed interference, soil organic carbon (SOC) and available nitrogen, an experiment was undertaken at the Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi (28°352 N latitude, 77°122 E longitude; altitude 228.6 meters above mean sea level) in 2017. There were 12 treatments, laid out in a randomized block design with three replications. The treatments included 8 BM treatments, involving two brown manure species (*Sesbania bispinosa*; *Crotalaria juncea*) sown at two seed rates (15 and 25 kg/ha) as sole/mixture (1:1), and were knocked down at two stages (25; 35 DAS) using 2,4-D 0.5 kg/ha. Four controls, namely, unweeded control, weed-free control, tank mixture of pendimethalin 0.75 kg/ha + atrazine 0.75 kg/ha, and atrazine 0.75 kg/ha + 1 hand-weeding 35 DAS (HW) were also adopted with BM treatments. In all BM treatments, pre-emergence application of pendimethalin 1 kg/ha was done.

Initial weed interference was minimized due to differential space capture effects of brown manure species that covered inter row spaces in maize crop, thus preventing weeds to come up. The BM with *Sesbania* + *Crotalaria* (1:1) 25 kg/ha (12.5 kg *Sesbania* + 12.5 kg *Crotalaria*) with 2,4-D at 35 DAS resulted in highest biomass production of brown manure species which suppressed weed interference. Being leguminous species, brown manure biomass is rich in N content with low C:N ratio which stimulated microbial activity. Rapid decomposition of biomass led to significant increase in soil organic matter, soil organic carbon and available N at harvest of maize crop. However, in terms of maize grain yield, the *Sesbania aculeata* and *Crotalaria juncea* mixture (1:1) 25 kg/ha (12.5 kg *Sesbania* + 12.5 kg *Crotalaria*) with 2,4-D application 25 DAS was found to be superior with comparable weed suppression. It may be concluded that *Sesbania aculeata* and *Crotalaria juncea* mixture (1:1) 25 kg/ha (12.5 kg *Sesbania* + 12.5 kg *Crotalaria*) with 2,4-D application at 25 DAS would be an optimum BM practice in maize for higher productivity with acceptable higher weed control efficiency.

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Long-term effect of herbicides on weed shifts in wheat in rice-wheat cropping system

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Rice-wheat is the predominant cropping system in India covering an area of about 11 million hectare. The farmers realize much of their food security from this cropping system. Weeds are serious constraints in this cropping system. Of late there are reports that weed flora has undergone a sea change with new weeds emerging while the incidence of some other weeds showing a declining trend. A long-term experiment on rice – wheat cropping system has been in place at Department of Agronomy of CSKHPKV, Palampur from 2000 till 2018. The soil of the test site was silty clay loam in texture, acidic in reaction and low in available N, P and K. The nine treatments so tested included farmers' practice, continuous use of herbicides (butachlor + 2,4-D) with 100% N through in organics or 25% N substitution through fresh *Lantana* leaves in rice followed by continuous use of isoproturon + 2,4-D or alternate use of isoproturon and clodinafop along with 2,4-D in wheat, alternate use of butachlor with pretilachlor with 100% N through inorganics or 25% N substitution through fresh *Lantana* leaves in rice followed by continuous use of isoproturon + 2,4-D or alternate use of isoproturon and clodinafop along with 2,4-D in wheat. Data have been recorded on the species- wise weed count and dry matter accumulation by weeds at maximum weed growth stage along with grain yield of wheat. At the start of the experiment *Phalaris minor*, *Avena ludoviciana*, *Vicia sativa*, *Anagallis arvensis* and *Coronopus didymus* were dominant weeds with highest population of *Phalaris minor*. However population density of all these weeds showed a declining trend over the years with some weeds such as *Coronopus didymus* were not observed after 2009–2010. However some other weeds like *Poa annua*, *Lolium temulentum, Polygonum* sp (*Polygonum hydropiper* and *P. alatum*) and *Alopecurus myosuroides* appeared in later years. Of late it has been observed that *Avena ludoviciana* has replaced *Phalaris minor* as the most pre–dominant weed in this trial. Significantly highest population of *Avena ludoviciana* has been observed in treatments where isoproturon has been continuously used for managing weeds in wheat as compared to the treatments where isoproturon and clodinafop has been alternately used. Similar results have also been reported for *Phalaris minor* and *Lolium temulentum*. Contrary to this higher population of *Poa annua* was observed in treatments where isoproturon and clodinafop has been alternately used as compared to the continual application of isoproturon. During *Rabi* 2017-18, *Avena ludoviciana* (28.8%), *Phalaris minor* (15.7%), *Poa annua* (15.7%), *Anagallis arvensis* (13.1%), *Lathyrus aphaca* (11.0%), *Vicia sativa* (10.4%) and *Lolium temulentum* (5.3%) were the main weeds which infested wheat field at maximum weed infestation stage while *Polygonum* sp and *Ageratum* sp appeared at a later stage. Rotational use of herbicide significantly reduced the weed growth and thereby increased the grain yield of wheat. All weed control treatments were superior to farmers' practice in increasing wheat grain yield. The findings of the present investigation conclusively inferred that weeds are dynamic in nature and their populations are largely influenced by cropping systems and management strategies adopted.

Chemical weed management in dual purpose tall wheat and residual effect of pendimethalin

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The use of wheat as a dual-purpose (DP) crop both for fodder and grain was aimed to avoid lodging in tall wheat cultivar and to reduce competition between area devoted to grain and fodder crops. During winters at the time of fodder scarcity in India, wheat can be harvested for quality fodder without any effect on grain production of wheat. There are many biotic and abiotic factors which are responsible for low wheat productivity, but weed infestation is one of the major biotic factors limiting wheat production and productivity. Wheat is infested with complex weed flora and major weeds in dual purpose wheat field were *Phalaris minor* Retz., *Anagallis arvensis* L., *Rumex dentatus* L., *Melilotus indica* All. Fl. Ped., *Medicago denticulata* Wild., *Coronopus didymus* (L.), *Convolvulous arvensis* L., *Cirsium arvense* (L). Scape, *Cyperus rotundus* L. *etc.* A field experiment "Chemical weed management in dual purpose tall wheat (*Triticum aestivum* L.) and residual effect of pendimethalin" was conducted to evaluate the different herbicides efficacy against both grassy and broad-leaf weed flora in dual purpose wheat during the *Rabi* seasons of 2015-16 and 2016-17 at Agronomy Research Farm, CCS HAU, Hisar (Haryana). The experiment was laid out in a RBD with 3 replications and 9 treatment combinations, *viz.* pendimethalin 1500 g/ha Pre-emergence (PE) alone and followed by (*fb*) post-emergence (PoE) application of pinoxaden 50 g/ha + metsulfuron 4 g/ha, sulfosulfuron + metsulfuron (30+2) g/ha and clodinafop + metsulfuron (60+4) g/ha at 2 week after cutting (WAC), alone application of pinoxaden 50 g/ha + metsulfuron 4 g/ha, sulfosulfuron + metsulfuron (30+2) g/ha and clodinafop + metsulfuron (60+4) g/ha at 2 WAC, weed free and weedy check. Before cutting, among herbicidal treatments, application of pendimethalin 1500 g/ha PRE provided significantly less weed dry weight and more weed control efficiency at 25 and 55 days after sowing (DAS) during both the years. After cutting of wheat for fodder, significantly increased weed control efficiency and reduced weed dry weight were observed under sequential application of pendimethalin 1500 g/ha PE *fb* pinoxaden + metsulfuron (50+4) 2 WAC, pendimethalin 1500 g/ha PE *fb* sulfosulfuron + metsulfuron (30+2) 2 WAC and pendimethalin 1500 g/ha PE *fb* clodinafop + metsulfuron (60+4) 2 WAC as compared to alone application of PE and PoE. Among different herbicidal treatments, significantly higher number of effective tillers, grain yield and B:C ratio was observed under sequential application of herbicides than alone application of herbicides during both the years of research. There were no pendimethalin residue in wheat fodder, grain, straw and soil. Thus, wheat fodder can be safely used for livestock.

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Control of *Phalaris minor* with pendimethalin in wheat

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In India, wheat (*Triticum aestivum* L.) is the second most important food grain after rice. Punjab is the major wheat growing state in India with an area of 3.5 million ha, 16.1 million tonnes of production, and productivity of 4583 kg/ha. *Phalaris minor* is a common grass weed which had caused serious problem for wheat productivity in Punjab. The continuous use of post-emergence herbicides alone had developed multiple or cross resistance to three modes of action of herbicides (photosystem II, ACCase, and ALS inhibitors). Occurrence of resistance in *P. minor* is one of the most important constraints for the decline in wheat productivity. Pendimethalin can provide good control of resistant and susceptible biotypes of *P minor*. The present study was conducted to fine tune the dose of pendimethalin for the management of resistant *P. minor* in wheat. The experiment was laid at research farm of Punjab Agricultural University, Ludhiana, during two *Rabi* seasons of 2014-15 and 2015-16 with five treatments, consisting of pendimethalin (Stomp 30 EC) at 750 g/ha, pendimethalin (Stomp 30 EC) at 930 g/ha, pendimethalin (Stomp 30 EC) at 1125 g/ha, pendimethalin (Stomp 30 EC) at 1500 g/ha and unsprayed check (control) in RBD design. Wheat variety '*HD 2967'* was sown on 4th November during 2014 and 2nd November during 2015 with seed rate of 100 kg/ha. Pre-emergence application of herbicide was done according to treatments with Knap sack sprayer using flood jet nozzle with 500 litres of water per hectare. Nutrients were applied to crop according the recommendation at the time of sowing and thereafter. The data of weed density was recorded at harvest using 50 ×50 cm quadrat. The grain yield was recorded at harvest. The weed data was analysed statistically after square root transformation. Application of pendimethalin has shown effective control by recording less density of *P. minor* over unsprayed check. Application of pendimethalin at 1500 g/ha recorded maximum weed control efficiency and found to be more effective in controlling *P. minor* and obtaining higher grain yield over other treatments. Weed control efficiency was increased as the dose of pendimethalin was increased from 750 g/ha to 1500 g/ha. Highest grain yield of 5.82 t/ha was recorded during 2014-15 with the application of pendimethalin 1500 g/ha and was statistically at par with pendimethalin 1125 g/ha. During 2015-16, grain yield of 5.98 t/ha was highest with application of pendimethalin at 1125 g/ha and was found statistically at par with pendimethalin 930 and 1500 g/ ha. Unsprayed check recorded the lowest grain yield of 3.7 t/ha and 3.91 t/ha during 2014-15 and 2015-16, respectively. Pre-emergence application of pendimethalin at 1125 g/ha provides effective control of resistant *Phalaris minor* in wheat.

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Weed flora and diversity indices in conservation tillage under soybean-wheat system in rainfed vertisols of central India

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Conservation tillage systems such as reduced tillage (RT) and no-tillage (NT) are options to check soil degradation, increase soil moisture availability and crop yield. These systems are now possible because of the availability of herbicides. However, weed management is a main concern of conservation tillage systems because of their influence on weed species shifts, survival and weed seed species distribution. To arrive at a suitable control measure, it is necessary to understand the effects of tillage on weeds, their densities and community distribution. Therefore, the present study was undertaken to measure the weed species diversity which occurred due to tillage treatments. In this experiment, observations on weeds were recorded periodically from four tillage treatments, *viz.* Conventional tillage (CT), mould board ploughing (MB), reduced tillage (RT) and no tillage (NT) like weed count and species distribution in terms of population density during the cropping seasons.

The observations on weeds were recorded periodically in soybean and wheat. The predominant weeds present in soybean during *Kharif* season were, *viz. Alternanthera sessilis, Digera arvensis, Convolvulus arvensis, Dinebra retroflexa, Digitaria* sp., *Echinochloa colona, Euphorbia* sp., *Eclipta alba, Anagalis arvensis, Cynodon dactylon, Cyperus* sp., *Commelina benghalensis, Celosia argentia, Phyllanthus niruri, Tridax procumbens*. Amongst these commonly observed weeds *Digitaria sanguinalis* competed the most with soybean. However, in first *Kharif* season, *Alternenthera sessilis* and *Trianthema portulacastrum* were observed as predominant weeds in the tilled plots. Further, it is well documented that changes in weed flora are driven by an interaction of several factors like tillage, environment, crop rotation, crop type and the timing and type of weed management practice. The herbicides glyphosate and pendimethalin were applied only in NT and RT plots in soybean controlled the weeds at early stages of crop. The lower weed density in NT was due to control of weeds by herbicides *i.e.* ghyphosate application over the top (OTP) along with pre-emergence application of pendimethalin. Compare to the *Kharif* season of soybean less number of weeds were observed in wheat during *Rabi* season.

The dominant weeds in wheat consists of *Cynodon dactylon, Digitaria* sp., *Saccharum spontaneum, Euphorbia* sp., *Convolvulus arvensis, Tridax procumbens, Launaea nudicaulis etc*. In wheat, as no herbicide was used to control weeds in either RT or NT, the higher weeds were recorded in NT than RT. In conventional tillage method *Alternanthera* sp. was observed as newly up-coming weed due to more tillage operations. The weed species *i.e. Euphorbia* sp. and *Cynodon dactylon* were observed throughout the season. Similarly, a typical winter season weed *Launaea nudicaulis* was also spotted only in NT and MB tillage system.

The diversity indices in terms of Simpson Diversity Index (SDI) and Shannon Weiner Index (SWI) were derived to measure weed diversity in both seasons. These indices (SDI and SWI) values were higher in CT and MB compared to NT and RT tillage system. Thus, diversity of weed species was more in treatments where tillage intensity was higher *i.e.* CT and MB. Thus, tillage operation carries weed seeds from one place to another which resulted in more diversity in tillage treatment. On the contrary, no tillage (NT) and reduced tillage (RT) resulted to lower weed diversity as there is no/less tillage intervention. Lower values of SWI in NT tillage system indicated that there is positive relationship between intensity of tillage and the weed diversity.

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Effect of conservation agriculture based crop establishment methods on weed management in rice-wheat system

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Conservation agriculture (CA) is recognized as holistic crop management option for achieving higher productivity and resource use efficiency. CA technologies involve minimum soil disturbance, permanent need based soil cover through crop residues or cover crops, and sensible diversification/crop rotations. Current crop production systems have faced the problem of weed infestation, soil degradation, higher cost, poor soil health, unstable crop production. Among these problem weed management has the crucial importance for achieving higher productivity and profitability. Hence keeping the above facts in mind an experiment was conducted on **"**Effect of Conservation Agriculture based Crop Establishment methods on Weed Management in Rice-Wheat system**"** at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.), India. The soil of the experimental field was sandy clay loam. The experiment was laid out in completely randomized block design with four replication and six crop establishment methods,*viz.* CE1: Conventional till puddled transplanted rice-Conventional till wheat [CT R–CT W (no residue retention/ incorporation)], CE2: conventional till puddled transplanted rice-conventional till wheat- conventional till mung bean [CT R-CT W-CT MB (Rice and Wheat residue removal, full mungbean residue incorporation)], CE3: conventional till direct seeded rice-zero till wheat [CT DSR-ZT W (anchored residue of Rice)], CE4: conventional till direct seeded rice-zero till wheat-zero till mung bean [CT DSR-ZT W-ZT MB (anchored residue of Rice and full mungbean residue incorporation)], CE5: zero till direct seeded rice-zero till wheat [ZT DSR-ZT W (anchored residue of Rice and Wheat] and CE6: zero till direct seeded rice-zero till wheat-zero till mung bean [ZT DSR-ZT W-ZT MB (anchored residue of Rice and Wheat and full mungbean residue retention)]. The crop was establish without any preparatory tillage in zero till base treatment (CE5 and CE6 in rice and CE3, CE4, CE5 and CE6 in wheat) with the application of glyphosate (1 kg/ha) before the seeding to knock down the weed. Full CA based treatments (CE5 and CE6) found significantly superior over other treatments in reducing weed density (no./m^2) and weed dry weight (g/m^2) in rice and CA based crop establishment methods (CE3, CE4, CE5 and CE6) were significantly effective among different crop establishment methods, in lowering weed density (no./m^2) and weed dry weight (g/m^2) compared to conventional methods (CE1 and CE2) in wheat. It can be concluded that ZT DSR-ZT W–ZT MB (CE6) crop establishment method with anchored residue of both the crop and mung bean crop residue retention will be helpful to achieve better weed management, higher yield, system productivity and system profitability in rice-wheat cropping system of eastern IGP.

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Effect of tank-mix application of herbicides against complex weed flora in *Kharif* maize

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Maize (*Zea mays* L.) is the most versatile and miracle food crop of global importance. It has immense potential to give high biological yield as well as grain yield in a short period due to its unique photosynthesis (C_4) mechanism hence, known as "Queen of cereals". In *Kharif* season maize fields are heavily infested with complex weed flora including grassy, broad-leaf weed and sedges which causes grain yield losses to the tune of 20 to 100% and controlling weeds in maize during critical period presumes utmost importance for realizing higher yield. For that, several methods are available *viz.* mechanical, cultural, biological and chemical but each method have their certain limitations, although chemical weed control is a better supplement to conventional methods and forms an integral part of the modern crop production because it is quick, more effective, time and labour saving method. Besides these, a single herbicide application having narrow-spectrum of activity and continuous application result in weed flora shift and they turn minor weeds into major weeds. The weed species which were either minor or non-existent earlier have now become more dominant to pose second generation weed problems these points towards the need to adopt herbicide combination. Looking to the above fact, a field experiment was conducted during *Kharif* season of the year 2017 at AICRP-Weed Management farm, AAU, Anand to study the effect of the tank-mix application of herbicides against complex flora in *Kharif* maize. The experiment was laid out in Randomized Block Design with 12 different pre-and post-emergence herbicides alone and their tank mix and inter-culturing *fb* hand weeding with 4 replications.

The results revealed that all the weed management practices proved to be significantly superior over weedy check with respect to controlling complex weed flora. However, tank mix application of topramezone 25.5 g/ha + atrazine 500 g/ha EPoE *fb* IC + HW at 40 DAS recorded lower weed density and total weed dry biomass with higher weed control index at 50 DAS and at harvest followed by atrazine + pendimethalin *fb* IC + HW at 30 DAS. Yields and yield attributing characters, *viz.* cob length, cob girth, no of grain/cob and growth and development characters, *viz.* Periodically plant height, Crop Growth Rate (CGR), Absolute Growth Rate (AGR), Leaf Area Index and chlorophyll content were also recorded higher in tank mix application of topramezone 25.5 g/ha + atrazine 500 g/ha EPoE *fb* IC + HW at 40 DAS. The extent of yield loss due to complex weed flora was to the tune of 52% due to heavy crop weed competition in weedy check treatment. There was no any carryover/residual effect of applied herbicides observed on succeeding wheat, mustard and chickpea crops.

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Effect of integrated weed management and different tillage practices on rice-wheat cropping system in the lower gangetic plains

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Rice-wheat systems of the IGP contribute substantially to global cereal production and the yield is contributed by type of tillage and weeds infestation, which reduce the yield. Nowadays sustainability of rice-wheat cropping system has been questioned with yield stagnation. Conservation tillage is becoming an increasingly accepted management technology in rice–wheat system in parts of the Indian IGP and weed management must aim at reducing the weed population to a level at which weeds occurrence has no effect on farmers' economic and ecological interests.

Keeping this in mind, two field experiments were conducted during two consecutive *Kharif* and *Rabi* seasons of 2013-14 and 2014-15 at RRSS farm of BCKV, Chakdaha, Nadia, W.B. to evaluate the performance of rice and wheat under different tillage practices; and also to find out the effective of integrated weed-management practices on productivity of rice-wheat system. The first experiment was on *Kharif* rice and laid out in a split-plot design, where puddling under transplanting (TPR) and dry tillage under direct seeding (DSR) were taken in main plots and five integrated weed management practices in sub-plots (including un-weedy check). Whereas, the second experiment was on *Rabi* wheat under a split-split plot design maintaining the respective tillage methods of rice in main plots and wheat was grown under conventional (CT) and zero till (ZT) conditions in sub-plots and five integrated weed management practices in sub-sub-plots (including un-weedy check).

The predominant weed species of rice were *Alternanthera sessilis, Eclipta alba, Ludwigia parviflora, Monochoria vaginalis* and *Phyllanthus niruri* among the broad-leaves; *Echinocloa colona, Paspalum scrobiculatum, Digitaria sanguinalis* and *Cynodon dactylon* among grasses and *Cyperus difformis, Cyperus rotundus* and *Fimbristylis miliacea* among sedges. DSR produced maximum number and dry weight of weeds except broad-leaves. Least total weed dry weight (15.09 g/m^2) at 60 DAT/DAS was recorded from pre-emergence application of pretilachlor at 0.5 kg/ha *fb* hand-weeding at 20 DAT/DAS and remained statistically at par with hand weeding twice at 20 and 40 DAT/DAS. Though the DSR (2.97 t/ha) gave the lower grain yield than transplanted rice (3.68 t/ha) but it gave the highest B: C ratio (2.13) over transplanted rice. Apart from this; direct seeded rice showed the better bulk density and soil micro flora than the transplanted rice which indicates the soil health improvement. The dominant weeds associated with wheat were *Chenopodium album, Cirsium arvense, Anagallis arvensis, Cynodon dactylon, Digitaria sanguinalis, Echinochloa colona* and *Cyperus rotundus*. Hand weeding at 15 DAS *fb* application of post emergence herbicide (sulfosulfuron + metsulfuron methyle) at 40 g/ha at 30 DAS gave the minimum total weed population and dry weight after hand weeding twice at 15 and 30 DAS.

Though ZT (2.55 t/ha) produced the lower grain yield than CT (2.73 t/ha) but the highest B: C ratio (1.85) recorded from ZT. Again it has been observed from the present investigation that ZT wheat improves the soil physical, chemical and biological properties by decreasing bulk density, improving nutrients uptake by the crop and increasing soil micro flora to ensure the long term sustainability of the system. The results indicate that conventional till-based rice–wheat system could be replaced with DSR *fb* ZT wheat system with effective integrated weed-management has the potentiality to reduce the weed problem and increase the system sustainability and productivity.

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Influence of tillage and weed management in maize-wheat cropping system

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Maize and wheat are the two important staple food crops of India and the contribution of this cropping system to total food grain production of the country is considerably large. Traditionally, maize and wheat are grown by broadcast seeding or with seed drill after 2–3 tillage operations. The traditional practice of growing these crops is laborious, costly and time consuming. Repeated conventional tillage coupled with other faulty land-utilization practices have caused large-scale degradation of our soils over the past 50–60 years. Hence, zero tillage is one of the better options that reduces the problems associated with faulty land utilization practices to certain extent. However, a combination of zero and conventional options in sequence needs to be standardized for each cropping, soil and microclimatic conditions in order to enhance the sustainability of systems and resource-use efficiency. Hence an experiment entiled 'Influence of tillage and weed management on maize-wheat cropping system' was conducted during *kharif* and *rabi* season of 2013-14 and 2014-15 at research farm of SKUAST-Jammu. The important weeds of the experimental site in the rainy season were *Cynodon dactylon, Echinochloa crusgalli* and *Setaria glauca* as grassy weeds*; Amaranthus viridis, Celosia argentea* as broad-leaf weeds and sedges, *viz. Cyperus rotundus*. While in the winter (*Rabi*) season, important weeds noticed were grassy weeds, *Phalaris minor, Poa annua,* and broad-leaf weeds, *viz. Medicago denticulata, Anagallis arvensis, Cirsium arvense* and *Chenopodium album*. In maize, among the different tillage treatments, lowest weed density and weed biomass and highest grain yield was recorded under conventional tillage in both maize and wheat crop. In weed management treatments lowest weed density and highest grain yield was observed in two hand weedings which was at par with atrazine at 1 kg/ ha. While in wheat, there was not any significant differences among different tillage treatments. However, among different weed management treatments metribuzin at 200 g/ha observed lowest weed density and biomass and highest grain yield which was at par with two hand weedings.

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Long-term farmer field experiment on comparative performance of post-emergence herbicides *vs* pre + post-emergence application of herbicides against *Phalaris minor* management in wheat

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To address poor control of little seed canary grass (*Phalaris minor*) weed in wheat, long-term On-farm trials on comparative performance of sole application of post emergence herbicide application v/s pre- + post-emergence (30-35 DAS) application of herbicides against *P. Minor* management in wheat were conducted at farmer's field in Yamunanagar district of Haryana from 2014-15 to 2017-18. Pre-emergence application of pendimethalin (30% EC) at 1500 g/ha followed by post-emergence application of either clodinafop at 60 g/ha resulted in 90, 97, 98 and 81% control of little seed canary grass in 2014-15, 2015-16, 2016-18 and 2017-18 respectively which culminated in substantially higher yield of wheat in this treatment over weedy check. On an average of four years, pre-emergence pendimethalin *fb* post emergence application of clodinafop increased yield of wheat (5.37 t/ha) to the tune of 10% over sole application of post emergence application of clodinfop (4.88 t/ha) and 68% over weedy check (3.20 t/ha). Unchecked growth of weeds (weedy check) can incur a loss of ` 30877/ha over sequential application of pre- and post-emergence application in wheat. Highest return on per rupee invested (2.49) was found to be in pre and post emergence application of pendimethalin and clodinafop respectively followed by 2.36 in sole application of clodinafop and least (1.66) in weedy check.

Yamunanagar, the plywood city of Haryana is most diverse district in terms of number of crops grown. Farming is one of the main source of livelihood security of district owing to ample supply of water, fertile lands, 1049 mm average rainfall (fig.1), warm weather and hardworking farming community. Among different crops, wheat is the most important cereal crop of the district. Widespread resistance in *Phalaris minor* is a major challenge for sustainable wheat production. From the past decade or so several chemicals have been tried for managing weeds in wheat. The development of herbicide resistance by certain weeds like *Phalaris minor*, wild oats *etc.* is mainly due to the use of single herbicides over a long period. Herbicides/chemical control are the most viable option for managing weeds due to uneven and untimely rainfall which make it difficult for manual weed control besides incurring more labour cost. Though the chemical method is being discouraged worldwide, however, its immediate effect and economic return cannot be ignored totally by the farmers of country like India. Instead the ill effects of herbicides can be minimized through their judicious use at recommended doses.

The trials were conducted at farmer's field in adopted villages (Bakana, Radauri, Allahar) of KVK Yamunanagar. The four season's pooled grain yield (5.37 t/ha), net returns (` 53631/ha) and BC ratio (2.49:1) was highest with pre-emergence application of pendimethalin + post-emergence application of clodinafop at 35 DAS which was significantly higher as compared to sole application of clodinafop and weedy check.

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Weed management in maize-based cropping system under conservation agriculture in central India

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Conservation agriculture technologies have been developed and adopted mostly in the rice–wheat cropping system in the alluvial soils of North-Western India. However, little work has been done in the other than rice–based cropping system being followed in the vertisols of central India, where crops like maize, mustard and greengram are grown on large areas. Weed management in such zero-till cultivation systems is a major issue responsible for low crop productivity. In view of this, an investigation was undertaken in maize based cropping system at ICAR–Directorate of Weed Research, Jabalpur during 2015–16 and 2016–17. The experiment with 16 treatment combinations was laid out in a split plot design with three replications. Results showed that zero-tilled maize with greengram residue retention with application of atrazine + pendimethalin *fb* hand weeding (HW) at 25 DAS produced 5.42 t/ha and 5.24 t/ha yield respectively in maize. Conventionally-tilled mustard resulted in 4.04 t/ha of seed yield whereas; application of pendimethalin *fb* HW produced 3.94 t/ha of seed yield in transplanted mustard. The zero-tilled greengram with retention of mustard residue gave 1.14 t/ha yield. Application of pendimethalin *fb* HW produced 1.06 t/ha of seed yield in greengram and resulted in significant reductions in weed growth and improved crop productivity. Treatment combination of zero tillage with preceeding crop residue 59.73 kg/ha/day with IWM gave the highest system productivity and RUE. This combination of treatments over a period of two years resulted in significant improvement in soil physical, chemical and biological properties. Therefore, a combination of zero-tilled crops with residue retention and IWM may be recommended for higher productivity, profitability and soil health of maize-based cropping system.

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Integrated weed management in late sown wheat under different tillage practices

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A field experiment was conducted during *Rab*i season of 2016-17 at the Agricultural Farm ($23^{0}40.1052$ N latitude, $87^{0}39.5212$ E longitude and 56 m altitude) of the Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal to study the effect of tillage and weed management practices on weed population dynamics and growth in late sown wheat. The experiment was laid out in split-plot design with three replications. Two tillage practices comprising of Zero tillage (ZT) and Conventional tillage (CT) were allocated to the main plot and eight weed management practices *viz.* pendimethalin 0.75 kg/ha, pendimethalin at 0.75 kg/ha *fb* wheel hoe at 30 DAS, pendimethalin 0.75 kg/ha *fb* straw mulching 4.0 t/ha at 20 DAS, pendimethalin 0.75 kg/ha *fb* clodinafop-propargyl 15% + metsulfuron-methyl 1% WP 0.40 kg/ha at 40 DAS, straw mulching 4.0 t/ha at 20 DAS, clodinafop-propargyl 15% + metsulfuron-methyl 1% WP 0.40 kg/ha at 30 DAS, weed free and unweeded control were assigned to the sub-plot. Wheat variety *'HD 2824'* was sown on December 13, 2016 with a seed rate of 120 kg/ha and cultivated following the recommended package of practices. Wheat crop was infested with eight weed species out of which *Digitaria sanguinalis, Echinochloa colona* among the grasses *Eclipta alba, Gnaphalium indicum*, *Polygonum plebeium, Solanum nigrum, Sphaeranthus indicus* and *Spilanthes calva* among the broad-leaved weeds were predominant throughout the cropping period. No significant difference was found between zero and conventional tillage with respect to density and biomass of grassy weeds, growth and yield attributes and yield of wheat. However, zero tillage registered significantly lower total weed biomass than conventional tillage at 45 and 60 DAS. Among the weed management practices sole application of straw mulching at 4.0 t/ha, pendimethalin at 0.75 kg/ha and clodinafop-propargyl + metsulfuron-methyl at 0.4 kg/ha registered only 48.1-50.1, 43.0-43.5 and 42.8-46.8% reduction in total weed biomass, respectively during 45 and 60 DAS. Integrated use of pendimethalin at 0.75 kg/ha *fb* straw mulching at 4.0 t/ha and pendimethalin at 0.75 kg/ha *fb* clodinafop-propargyl + metsulfuron-methyl 0.4 kg/ha registered 91.8-91.9 and 87.2-89.7% reduction in total weed biomass, respectively during 45 and 60 DAS. Weed competition caused yield reduction of wheat to the tune of 45.10%. Lower values of weed index (4.74 and 8.38%), higher number of ears (378 and 352/m^2) and yield (4.19 and 3.77 t/ha) of wheat, were registered with combination of zero tillage with integrated use of pre-emergence herbicide pendimethalin at 0.75 kg/ha with straw mulching at 4.0 t/ha at 20 DAS and pre-emergence application of pendimethalin at 0.75 kg/ha followed by post-emergence herbicide clodinafop-propargyl + metsulfuron methyl at 0.4 kg/ha. Thus zero tillage along with integrated use of pre-emergence herbicide pendimethalin at 0.75 kg/ha with straw mulching at 4.0 t/ha at 20 DAS and pre-emergence application of pendimethalin at 0.75 kg/ha followed by post-emergence application of clodinafop-propargyl + metsulfuron-methyl at 0.4 kg/ha appeared to be promising approaches for effective weed management and obtaining higher yield and profitability of late sown wheat.

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Effect of herbicides and their combinations on broad-leaved weed flora and grain yield of wheat

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Wheat is one of the important staple food crops in India. Wheat is infested with diverse weed flora, as it is grown in diverse agro-climatic conditions, under different cropping sequence, tillage and irrigation regimes. Weeds compete with wheat crop for moisture, nutrients, light and space and reduced yield from 20-50% depending on the weed species and their density. Sometimes broad-leaved weed density is much higher than grass weeds particularly in area where grass killers are used continuously without addition of broad-leaf weed herbicides. Broadleaved weeds like *Anagallis arvensis*, *Euphorbia helioscopia*, *Medicago denticulata*, *Melilotus indica*, *Vicia sativa*, *Chenopodium album*, *Rumex maritimus*, *Lathyrus aphaca*, *Fumaria parviflora*, *Trachyspermum* sp., and *Cirsium arvense* are infesting wheat in sub-tropical belt of Jammu. Metsulfuron, 2, 4-D and carfentrazone is used for control of broad-leaved weeds in wheat crop. But some of the post-emergent broad-leaved weed herbicides are less effective on advanced stage weeds/hardy weeds and unable to control the later weeds emerge after application due to its lack of residual activity in soil. To widen the spectrum of weed kill and to provide the season long weed control, the use of herbicide mixture is advisable with or without surfactant. Hence, a comprehensive study was undertaken to keep the broad-leaved weeds below threshold level and assess the effect of different herbicide and herbicides mixtures on yield performance of wheat. A field experiment was conducted during two consecutive years 2016-17 and 2017-18 at Research Farm, Chatha, SKUAST-Jammu to find out the effect of different herbicides and its combination on broad-leaved weed population and yield of wheat crop. The experiment comprised of 11 treatments *i.e.* halauxifen + florasulam + polyglycol 12.76 g/ha, metsulfuron + surfactant 4 g/ha, carfentrazone 20 g/ha, 2, 4-D Na 500 g/ha, 2, 4-DE 500 g/ha, metsulfuron + carfentrazone + surfactant 4+20 g/ha, 2, 4-D Na + carfentrazone 400+20 g/ha, 2, 4-DE + carfentrazone 400+20 g/ha, halauxifen + florasulam + carfentrazone + surfactant 10.21+20 g/ha, weedy check, weedy free in RBD design with three replication. The soil of the experiment field was sandy loam in texture, low in organic carbon (0.45%) and available nitrogen (170.50 kg/ha), medium in available phosphorus (14.25 kg/ha) and low in available potassium (140 kg/ha). The pooled data of two years revealed that minimum weed density (6.33 no.) was recorded in metsulfuron + carfentrazone + surfactant after 60 days of spray followed by 2, 4-DE + carfentrazone with weed density of 7.67 no. The test weight of wheat in all the treatments varied between 35 to 39 g and they were found statistically non-significant whereas the maximum grain yield (4.99 t/ha) was recorded in treatment metsulfuron + carfentrazone + surfactant followed by 2, 4-DE + carfentrazone with value of 4.88 t/ha. However, minimum grain yield was recorded in weedy check (3.49 t/ha). From the present study it is concluded that fields having diverse infestation of broad-leaved weeds require herbicides combination. Metsulfuron-methyl + carfentrazone 4+20 g/ha + surfactant and 2, 4-D E + carfentrazone 400+20 g/ha were effective against diverse broadleaf weeds in wheat.

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Role of conservation agriculture in weed dynamics and productivity of maize-wheat cropping system

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The experiment was conducted at Birsa Agricultural University, Ranchi, Jharkhand during 2015-16 and 2016-17. The experiment was laid out in strip plot design with five tillage sequences in main plots, *viz.* conventional-conventional (CT-CT), conventional-zero (CT-ZT), zero-zero (ZT-ZT), zero-zero with crop residue (ZT-ZT+R) and zero tillage along with crop residues in both the seasons (ZT+R-ZT+R) while three weed control methods in sub plots, *viz* recommended herbicides in maize (atrazine at 1 kg/ha pre-emergence) and wheat (isoproturon at 0.75 kg/ha + 2,4-D at 0.5 kg/ha post emergence), IWM in maize (pendimethalin 1 kg/ ha + intercrop black gram) and in wheat (isoproturon at 0.75 kg/ha + 2,4-D at 0.5 kg/ha post emergence + mechanical weeding at 40 DAS) and weedy check respectively. The pooled analysis of two years data revealed that CT-CT sequence producing significantly reduced dry matter accumulation by total weeds compared to rest of the tillage sequences produced 36.5 and 39.85 per cent significantly reduced weed dry matter compared to maximum observed under ZT-ZT sequence *i.e.* 56.00 and 18.27 g/m^2 respectively. Among weed control methods, IWM recorded significantly reduced total weed dry matter accumulation compared to weedy check. The reduction was 57.57 and 53.51 percent compared to maximum total dry matter accumulation observed under weedy check *i.e.* 68.41 and 19.08 g/m^2 in maize and wheat respectively. CT-CT sequence being similar to ZT+R-ZT+R recorded 34.25 and 23.60 per cent significantly higher wheat grain yield compared to minimum observed under ZT-ZT sequence *i.e.* 25.78 and 3.74 t/ha. The CT-CT tillage similar to ZT+R-ZT+R recorded 19.95 and 34.25% higher maize and wheat grain yield respectively than ZT-ZT tillage. Among weed control methods, application of integrated weed management gave 108.96 and 43.67% higher maize and wheat grain yield respectively than weedy check. Continuous conventional tillage in maize and wheat recorded maximum gross (` 26,909 and 16562/ha) and net returns (` 25,412 and 15063/ha) while among weed control methods, application of integrated weed management in maize and wheat gave maximum gross (` 44,491 and ` 20,238/ ha) and net returns (` 34,715 and ` 17,080/ha) of maize and wheat production respectively than that recorded under respective weedy check treatments.

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Effect of tillage, establishment methods and weed management practices on weeds and wheat in maize-wheat cropping system

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A field experiment was conducted at Research Farm of IARI Regional Station Pusa, Samastipur Bihar during *Kharif* season of 2015-16 and 2016-17 to study the tillage, method of establishment and weed management practices on performance of wheat in maize-wheat cropping system in NEPZ of India. The treatments consist of three tillage and planting techniques namely, CT - Flat Bed, ZT - Flat Bed, ZT - Raised Bed (Permanent) in main plot and seven weed control measures including one weedy check and weed free check in sub plot. The experiment was conducted in Split Plot Design with three replications. The variety of wheat used for study was '*HD 2967*'. Based on two years data, it was observed that among three tillage and crop establishment techniques ZT - Flat Bed and ZT - Raised Bed were at par with respect to weed density and weed dry weight. Highest weed density and weed dry weight were recorded in ZT - Flat Bed followed by ZT - Raised Bed and lowest weed density and weed dry weight was observed with CT - Flat Bed. The highest yield was observed in CT - Flat Bed (5.27 and 5.97 t/ha) followed by ZT - Raised Bed (4.88 and 5.48 t/ha) and ZT - Flat Bed (4.19 and 4.87 t/ha) during 2015-16 and 2016-17, respectively. Among weed control measures the lowest weed density and weed dry weight were observed in the plots having two hand weeding followed by application of isoproturon + two hand weeding at 45 DAS. The ready mix herbicide, sulfosulfuron + metsulfuron at 40 g/ha as post-emergence at 30 DAS was found superior over herbicide mixture of isoproturon at 750 g/ha + 2,4-D at 250 g/ha post-emergence at 30 DAS with respect to weed density, yield and yield attributing characters. Significantly highest grain yield were recorded in the plot having two hand weeding (4.9 and 5.62 t/ha) followed by the application of isoproturon + two hand weeding at 45 DAS (4.86 and 5.57 t/ha) during 2015-16 and 2016-17, respectively.

Effect of topramezone and tembotrione on weeds and maize

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Weed management is a severe issue in forage crop production and weeds play a large piece in maize production. Worldwide yield losses in maize due to weeds are estimated to be around 37%. Weeds reduce crop yield by competing for light, water, nutrients and carbon di oxide, interfere with harvesting and increase the cost involved in crop production. The infestation of weeds is increasing day by day in the maize growing belt of the state especially where the farmers are using atrazine year after year. Therefore, the new herbicides has been tested for the full expression of the production potential of forage crops depends on the degree of weed infestation. A field experiment was conducted at Research Farm, AICRP on Forage Crops, Department of Agronomy, JNKVV, Jabalpur (Madhya Pradesh) during *Kharif* season of the year 2016-17. The soil of the experimental field was neutral in reaction (pH 7.2), and low in organic carbon (0.53%) as well as with medium available nitrogen (255.00 kg/ha), medium available phosphorus (17.18 kg/ha) and medium available potassium (315 kg/ha) contents with normal electrical conductivity (0.32). Eight treatments consisted with pre emergence application of atrazine 1000 g/ha, post emergence application of 2,4-D 500 g/ha, tembotrione 120 g/ha and topramezone 35 g/ha alone, combined application of tembotrione 120 g/ha + atrazine 250 g/ha, topramezone 35 g/ha + atrazine 250 g/ha, hand weeding twice at 20 and 40 DAS and weedy check were tested in a randomized block design with three replications. Sowing of maize cv. African Tall was done on 1st July, 2016 by using the seed rate 40 kg/ha as per treatments in the rows 60 cm apart. The predominant weed flora were *Echinochloa crus-galli* L., *Cyperus rotundus* L. and *Cynodon dactylon* L. among monocots and *Digera arvensis* L., *Amaranthus viridis* L., *Portulaca oleracea* L., *Alternenthara sessilis* L. and *Trianthema* spp. among dicots. Post emergence application of topramezone 35 g/ha, tembotrione 120 g/ha and combined application of topramezone 35 g/ha + atrazine 250 g/ha, tembotrione 120 g/ha + atrazine 250 g/ha significantly reduced the infestation of all associated weeds over weedy check and was found most effective in paralyzing the weed growth to that of 2, 4-D 500 g/ha and atrazine 1000 g/ha alone. The grain (2818.0 kg/ha) and stover (22750.0 kg/ha) yields were maximum with hand weeding twice at 20 and 40 DAS,which were comparable between to those obtained with the post emergence application of topramezone 35 g/ha + atrazine 250 g/ha (2616.6 kg/ha and 21250.0 kg/ha, respectively).

Yield and nutrient uptake of summer maize under various tillage and weed management practices and impact on soil health

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A field experiment involving three different tillage methods *i.e.* conventional tillage (CT), minimum tillage (MT) and zero tillage (ZT) and six different type of weed management practices *viz.* atrazine 1.25 kg/ha pre-emergence (W_1), 2,4-D 0.5 kg/ha post-emergence (W_2), W_1 + W_2 (W_3), atrazine 1.25 kg/ha pre-emergence + one hand weeding at 30DAS (W_4), two hand weeding at 15 and 30 DAS (W_5) and weedy check (W_6) was tested in split plot design with three replications during summer season of 2014 at Agronomy Main Research Farm, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha. Three tillage methods were allocated to main plots and six weed management practices to subplots. The soil of the experimental site was sandy loam with pH of 5.91, EC of 0.52 dS/m, OC 0.693%, available N 287.57 kg/ha, available P 40.57 kg/ha and available K_2O 289.50 kg/ha. '*Nilesh (NHM-51)*' was sown on 21 January in zero tilled plots and 05 February in minimum and conventionally tilled plots. The crop was harvested on 05 May in zero tilled plots and 15 May in minimum and conventionally tilled plots. In total, 24 species of weeds infested the maize crop. Both tillage and weed management acted synergistically to the advantage of the crop growth and development. Zero tillage gave the maximum grain yield of 6.73 t/ha and atrazine + one hand weeding gave the maximum grain yield of 7.62 t/ha, but atrazine + one hand weeding under zero tillage gave the grain yield of 8.08 t/ha. Similarly, the maximum stover yield under zero tillage, atrazine + one hand weeding and atrazine + one hand under zero tillage weeding were 8.78, 9.62 and 10.10 t/ha, respectively. Zero tillage recorded the maximum uptake of 82.32, 16.07 and 18.65 kg of N, P and K/ha through grain and 35.47, 21.28 and 104.66 kg N, P and K/ha, respectively, by stover. Application of atrazine + one hand weeding recorded the maximum uptake of 91.03, 17.37 and 19.78 kg N, P and K/ha by grain and 37.71, 22.23 and 109.16 kg N, P and K/ha by stover. Among tillage practices, zero tillage and weedy check amongst weed management recorded the maximum values of microbial biomass carbon in soil, macro-aggregates, organic carbon, population of bacteria, actinomycetes and fungi and the minimum values of electrical conductivity and bulk density of soil after harvest.

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Tank mix efficacy of new generation herbicides on productivity and profitability of maize in Telangana

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Maize is one of the important rainy season crops of Telangana, which has brought about a perceptible change in the economy of the farmers. Control of grasses and sedges is a problem for the farmers, especially when the too high or too low soil moisture hinders the intercultural operation and scarcity of labour during critical stages of weeding. Hence a field experiment was conducted during *Kharif*, 2017 to evaluate the tank mix efficacy of new herbicides topromezone and tembotrione in combination with atrazine. The experiment was laid out in randomized block design with ten treatments replicated thrice and maize hybrid DHM-117 was used.

The experimental field was infested with *Cynodon dactylon, Digitaria sanguinalis*, *Dactyloctenium aegyptium, Echinocloa spp* and *Rottboellia exaltata among grasses; Parthenium hysterophorus, Commelina benghalensis, Amaranthus viridis, Euphorbia geniculata, Digera arvensis* and *Trianthema portulacastrum* among the broad-leaved weeds and sedge *Cyperus rotundus.* Topromezone + atrazine at 25.2+250 g/ha + MSO recorded lower density of grasses (4.50/m^2) and broad leaved weeds (3.56 /m^2) which was at par with tembotrione + atrazine at 105+250 g/ ha + stefes mero adjuvant (6.0/ m^2 and 4.38/m^2) and atrazine 1.0 kg/ha *fb* intercultivation at 30 DAS (5.30 /m^2)

Topromezone + atrazine at 25.2+250 g/ha + MSO adjuvant recorded significantly lower weed dry matter (16.73 g/m^2) which was at par with tembotrione + atrazine at 105+500 g/ha + stefes mero (18.23 g/m^2), intercropping with cowpea and pendimethalin at 1.0 kg/ha as pre-emergence (18.93 g/m2) and atrazine at 1.0 kg/ha as pre-emergence followed by IC at 30 DAS (20.34 g/ m2). Maximum grain yield (6.58 t/ha) was recorded in hand weeding at 20 and 40 DAS which was 60.5% over the unweeded control and on par with topromezone + atrazine at 25.2+500 g/ha + MSO as PoE (6.44 t/ha) with 59.6% increase over the unweeded control and tembotrione + atrazine at 105+250 g/ha + stefes mero as PoE (6.28 t/ha) with 58.7% increase over the control.

Higher Benefit: Cost ratio was recorded in tank mix of topromezone + atrazine at 25.2+250 g/ha + MSO as PoE (3.17) followed by atrazine as PE followed by intercultivation at 30 DAS (3.11). Tank mix application of topromezone (25.2 g/ ha) or tembotrione (105 g/ha) with lower doses of atrazine at 500 g/ha along with adjuvants is effective in controlling the weeds and recording higher yield under labour scarce conditions in *Kharif* maize.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Effect of weed management on weed and yield performance of wheat under eucalyptus tereticornis based agroforestry system

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Agroforestry is a sustainable land use system where two or more component are growing simultaneously on the same unit of land, where one component is annual crop and second is woody perennial. India is the first country in the world has implemented the National Agroforestry Policy in 2014, under its Ministry of Agriculture and Farmers Welfare. Its objective is to expand tree plantation in combination with crops and/or livestock to improve overall productivity, reducing unemployment, generating additional source of income and livelihood support to small landholders. Moreover, in this direction, efforts have been made by the farmers and researchers for introducing promising tree based farming systems across the different states in order to attain sustainability.

Wheat (*Triticum aestivum* L.) is widely intercropped cereal crop during *Rabi* season (November - April) with Eucalyptus, Poplar, and other fast growing tree species in all over india. In agroforestry systems, reduction in yield of wheat is generally observed under the shade of tree crown and weeds due to resource competition. Weed infestation is one of the major factor limiting crop productivity.

Hence, a field experiment was conducted during winter season to find out the effect of herbicides on weed dynamics and yield performance of wheat (*Triticum aestivum* L.) variety 'LOK-1' in randomized complete block design with three replications under eucalyptus based agroforestry system. An experiment was conducted at the farmer's field village- Majitha, District- Jabalpur during the Rabi season of 2016-17 and 2017-18. The field was infested with 5 major weed species *Phalaris minor, Rumex dentatus, Melilotus indicus, Chenopodium album* and *Launaea nudicaulis* during both the year. The average relative density of grassy weeds *Phalaris minor* (14.97 and 16.51%) and broad-leaved weeds *Rumex dentatus* (28.74 and 22.02%) along with *Chenopodium album* (22.75 and 21.10%), *Launaea nudicaulis* (17.96 and 20.18%), *Melilotus indicus* (15.57 and 20.18%) during 2016-17 and 2017-18, respectively. The hand weeding showed minimum total weed density and weed dry weight, proved more effective than all weed control treatments and over weedy check. Among chemical weed control treatment 2, 4-D 0.5 lit/ha + hand weeding 30 DAS and 2, 4-D 0.5 lit/ha *fb* metribuzin 0.250 kg/ha, metribuzin 0.250 kg/ha have control both broad-leaf and grassy weed and clodinafop-propargyl 0.140 kg/ha control grassy weed over weedy check. The application of 2, 4-D 0.5 lit/ha *fb* metribuzin 0.250 kg/ha (77.03 and 80.41%), 2, 4- D 0.5 lit/ha (75.15 and 83.00%) and 2, 4-D 0.5 lit/ha + hand weeding 30 DAS (75.18 and 77.60%) was found higher weed control efficiency during both the year. The hand weeding showed maximum weed control efficiency (86.73 and 95.51%) and proved superior over herbicidal treatments. The higher grain yield and straw yield was found under hand weeding 30 DAS (1.97, 1.82 and 4.65, 3.97 t/ha) during both the year. Among chemical weed control treatment clodinafop-propargyl 0.140 kg/ha found higher yield attributing traits, nutrient uptake by wheat, grain yield and straw yield under Wheat-Eucalyptus tereticornis based agroforestry system. The hand weeding increase grain yield 33.82 and 33.68% during both the year under Wheat-Eucalyptus tereticornis based agroforestry system.

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Evaluation of different pre- and post-emergence herbicides in *Kharif* maize and their residual effect on succeeding wheat crop

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A field experiment was conducted at Regional Research Station, Karnal during *Kharif* 2015 and 2016 and *Rabi* 2015-16 and 2016-17 to evaluate different herbicides in *Kharif* maize and their residual effect on succeeding wheat crop. The experiment was conducted in Randomized Complete Block Design and comprised of seventeen treatment combination applied in *Kharif* maize. The treatments were atrazine 750 g/ha PRE (T_1), atrazine 1000 g/ha PRE (T_2), atrazine 750 and 500 at PRE and 35 DAS (T_3), atrazine 750 g/ha as PRE *fb* 2, 4-D 500 g/ha at 35 DAS (T_4), atrazine 1000 g/ha as PRE *fb* one hoeing at 35 DAS (T_5), one hoeing at 20 DAS *fb* atrazine 500 g/ha at 35 DAS (T_6), alachlor 2000 g/ha as PRE (T_7), alachlor 2000 g/ha as PRE *fb* hoeing at 35 DAS (T_8), alachlor 2000 g/ha as PRE *fb* 2, 4-D 500 g/ha at 35 DAS (T_9), atrazine 375 g/ ha+ alachlor 1000 g/ha as PRE (T_{10}), tembotrione 120 g/ha + S at 35 DAS (T_{11}), tembotrione 140 g/ha + S at 35 DAS (T_{12}), alachlor 2000 g/ha as PRE *fb* tembotrione 120 g/ha + S at 35 DAS (T_{13}), atrazine 1000 g/ha as PRE *fb* tembotrione 120 g/ha + S at 35 DAS (T_{14}), hoeing twice at 20 and 35 DAS (T_{15}), weedy check and weed free.

Major weed species infesting the experimental field were *Cyperus rotundus, Brachiaria reptans, Dactyloctenium aegyptium, Amaranthus viridis, Digera arvensis, Phyllanthus niruri* and *Portulaca oleracea*. The treatment alachlor 2000 g/ha as PRE- *fb* tembotrione 120 g/ha + S at 35 DAS (T_{13}) provided excellent control of all types of weeds at different stages of the crop growth during both year of experimentation. Among herbicide treatments at 50 DAS, alachlor 2000 g/ha as PRE *fb* tembotrione 120 g/ha provided highest weed control efficiency (94.6 and 95.6%) during both the years. Maximum grain yield (6.50 and 6.90 t/ha) and yield attributes of maize were obtained in weed free treatment which was statistically at par with alachlor 2000 g/ha as PRE *fb* tembotrione 120 g/ha + S at 35 DAS (T_{13}) (6.38 and 6.82 t/ha). No visual phyto-toxicity of any applied herbicide was observed in maize crop.

All herbicide treatments employed in *Kharif* maize, irrespective of their dose and application time did not show any residual carryover effect on succeeding wheat because of rapid microbial degradation of herbicides due to four flood irrigation applied to *Kharif* maize and occurrence of 377.8 and 501.7 mm of rainfall between the time of application of herbicides and sowing of succeeding wheat crop.

Effect of different date of sowing on the weed dynamics in wheat in Madhya Pradesh

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Rice-wheat is a major cropping system, which holds about 18 million hectares (Mha) area in Asia out of which 10 Mha (55.56%) in Indo-Gangetic plains. India ranked second in wheat production (93.5 MT) after China. Weeds are the limiting factor for the agriculture. Weed infestations reveals the ecological consequences of management practices in the current and previous years as well as edaphic characteristics of the site and regional climate. The development of an integrated weed management system requires detailed information on weed; crop interactions, including the relative competitive ability of the crop during various phases of development on weed growth. Delayed sowing reduced the emergence and survival of weed species in winter wheat. Now a day's changes in the day and night temperature during winter season and there is changes in the weed dynamics and flowering period consequently decreasing in wheat productivity. Therefore, study on effect of different date of sowing on the weed dynamics was undertaken in wheat crop.

A field experiment was conducted during rabi season 2017-18 at Research farm of ICAR-Directorate of Weed Research, Jabalpur, M.P., India (23°23'31.15" N and 79°96'81.32" E). The soil of the experimental site was classified as typic chromusterts with sandy loam texture, 0.48% organic C, 238 kg/ha available N, 16.4 kg/ha available P and 340 kg/ha available K. The wheat crop was sown at six different dates of ten days interval from 21/10/2017 to 10/12/2017. The experiment was laid out in Randomized Block Design with three replications. The major weed flora during the experimental period were *Medicago polymorpha*, *Avena ludoviciana*, *Phalaris minor*, *Physalis minima*, *Amaranthus viridis etc.* Weed density and dry weight were taken at 60 days after sowing of wheat crop. Among the different dates of sowing the maximum weed density and dry weight were recorded wheat the crop was sown late *i.e.* 10th December. The density of *Phalaris minor* and *Avena ludoviciana* were highest when the crop was sown late (10/12/2017), but the density was minimum with ideals sowing date. *Medicago polymorpha* remain abundant during all date of sowing of wheat crop. *Cyperus* spp. was observed during early date of sowing and *Echinochloa colona* during late sowing. The different dates of sowing had not any significant effect on spike length and spike weight of wheat crop. Whereas, number of spike per m^2 were varied significantly with different dates of sowing of wheat crop. Sown crop among the different dates of sowing, the higher wheat grain yield was recorded when the crop was sown during mid-November, *i.e.* 10th and 20th November. Delaying the sowing of wheat beyond the November, drastically reduced the grain yield due to the terminal heat during the months of April. Thus weed density during the first fortnight sowing of November (10-20 Nov.) was lowest and yielded the maximum.

Impact of OFR on weed management technology in wheat at farmer's field

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As the harbinger of green revolution wheat has played a key role in achieving self-reliance in the food production in the country. With the introduction of higher yielding varieties of wheat responsive to intensive irrigation and fertilizers application, wheat production increased from 75 MT during 2006-07 to 94 MT in 2016-17. However, there is still wide gap between potential yield of wheat and yield obtained at farmer's field. Indian farmers are now convinced with the role of quality seeds, fertilizers and irrigation in wheat production and they do apply these inputs as per their economic conditions and availability, however, very few resourceful farmers are aware of the role of weed management in increasing the wheat productivity. *Phalaris minor* and W*ild oat* are serious weeds of wheat crop especially where wheat follows rice. Control of these weed through herbicide is more efficient than mechanical weeding and helps in improving the efficiency of applied nutrients and production of quality produce. Adoption of rice-wheat cropping system favoured. *P. minor* & *Wild oat* growth and thus became a troublesome weed. At present large area of wheat is treated with herbicides to control these weed in wheat crop.

Keeping in view the above facts, the study was conducted in Madhya Pradesh to find out the present status of adoption of chemical weed control technologies against grassy weeds (*P. minor* & *Wild Oat*), stages of non-adoption of this practice, constraints and suggestions of farmers for bringing further improvements in it. On the basis of the interview with 147 farmers, it was recorded that 87% had not fully adopted this practice in wheat crop. Half of the respondents had not adopted it at the knowledge stage of innovation decision process due to ignorance. The reasons for non-adoption of this practice were lack of knowledge (42%) and lack of guidance (24%). About 65% of farmers suggested that extension system should publicize the method of chemical use and highlight its instructions through mass media in advance. It was also found that major factor responsible for non-adoption of this practice was due to ignorance (50%), followed by in appropriateness (32%), inability (9%) and unwillingness (9%). The lack of knowledge of details of recommendation was probably the cause of using lower dose, improper spray and choice of wrong herbicides.

Impact of OFR cum demonstration on tribal maize growers

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India is one of the top 10 maize producers in the world. The total area for maize in India is 94 lack hectares and 70% of it, is cultivated under rain fed conditions (India maize summit 2014). The state of Madhya Pradesh is one of the traditional maize growing states, and accounts for 13 % of the total maize area. However, its productivity when compared to other maize growing states is very low. The low productivity level of maize in Madhya Pradesh is primarily due to inability of the majority of farmers particularly in tribal localities, to follow the recommended package of practices either due to high cost or lack of awareness. Therefore, an attempt was made to address the improved technological interventions including weed management issues through on- farm research trials (OFRT) in the field of some tribal farmers.

Initially, survey was made in maize growing tribal locality of Narayangunj tehsil (Bhawal, Goojarsani and Bijegaon villages) of Mandla district (MP). The soils were poor having low fertility level and organic carbon. Farmers were illiterate and backward in terms of modern agricultural technologies. They used to grow only local varieties of maize without any application of fertilizers and modern weed management practice. Twenty five OFR-cum-demonstration trials on improved technologies including weed management under conservation agriculture were laid out at purposively selected farmer's field in a participatory mode in maize crop during *Kharif* 2015- 2016. The objective of this OFR trial was to make aware/educate the tribal farmers about improved agricultural technologies.

The improved technologies including weed management under OFR-cum-demonstration were found effective in increasing grain yield of maize by 60-85% over farmers practice depending upon the intensity and growth of weeds, and gave an additional economic benefit of ` 16000-18000/ha over farmer's practices. Weed control efficiency and benefit-cost ratio of the imposed treatments were 70-75 % and 1.93-2.15, respectively. It was observed that farmers practice, *i.e.* manual weeding at in appropriate stages of crops (at later stages of crop growth so that they can use weed biomass as fodder), has no relevance over the crop yield and economy. It was also observed that few resourceful farmers were aware of the role of recommended dose of fertilizer, line sowing and improved weed management technology in enhancing the overall crop productivity but still continuing the conventional practice of unbalanced use of fertilizer, broadcast method of sowing and manual weeding owing to various social, economical and other constraints prevailing in tribal localities. A general comparison of the costs of cultivation of traditional and hybrid cultivars has revealed that the cost increases on using the improved cultivars due to higher requirements of fertilizers, irrigation, herbicides and plant protection chemicals as compared to that needed for the traditional varieties. However, with the significant increase in yield, the cost of production per unit amount of grain yield has been much lower in case of the improved cultivars. Thus, the maize yield and farmer's income of these localities can be increased through adoption of proper technologies.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Weed management in rice-wheat–mungbean cropping system under conservation agriculture

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Rice-wheat cropping is a very common and widely adopted practice in India. In central India, rice and wheat are generally grown under conventional tillage system, which involves intensive tillage operations virtually clean cultivation with complete removal of crop residues and other biomass from the field. Rice grown traditionally with transplanting method requires large amount of energy, in the form of diesel, machinery, labour, water and often delayed planting of succeeding crop along with formation of hard pan which creates problem and again requires more energy for preparation of seed bed for succeeding wheat crop. Conservation agriculture lead to improve system productivity, decrease cost of cultivation and produce higher income. But severe weed infestation is a major constraint in conservation agriculture. Thus, for effective and sustainable weed management and delay in herbicide resistance, suitable weed control is very necessary. Hence, the present investigation entitled "Weed management in rice-wheat–mungbean cropping system under conservation agriculture" was carried out at ICAR-Directorate of Weed Research, Mahajpur, Jabalpur 482004 to study the effect of tillage and weed management on weed dynamics in rice-wheat-mungbean cropping system and getting higher system productivity. The experiment was consisted of fifteen treatments comprising of five tillage practices as main plot treatments *viz.*, conventional tillage in rice + *Sesbania*-conventional tillage in wheat-zero tillage in mungbean, conventional tillage in rice + *Sesbania* + mungbean residues-conventional tillage in wheat + rice residues zero tillage in mungbean + wheat residues, zero tillage in rice + *Sesbania* - zero tillage in wheat-zero tillage in mungbean, - zero tillage in rice + *Sesbania* + mungbean residues-zero tillage in wheat + rice residue-zero tillage in mungbean + wheat residues, conventional tillage in transplanted rice-conventional tillage in wheat and three weed management as sub plot treatments *viz.*, weedy check, regular application of bispyribac 25 g/ha in rice and application of tank mix solution of clodinafop 60 g/ha and sulfosulfuron 25 g/ha in wheat (during both the years) and rotational application of chlorimuron + metsulfuron-methyl 4.0 g ready mix/ha during first year and bispyribac 25 g/ha during second year in rice and application of clodinafop 60 g/ha + 2, 4-D 0.5 kg/ha during first year and mesosulfuron + iodosulfuron-methyl 12 + 2.4 g/ha during second year in wheat, were laid out in split plot design .There was predominance of *Cyperus iria, Dinebra retroflexa* (48.57%) and *Echinochloa colona* (21.88%) in rice as both had higher relative density. However, other weeds like, *Dinebra retroflexa* and *Caesulia axillaris* were also present in lesser numbers (7.33 and 5.19%) respectively. Similarly *Medicago denticulata* was rampant in wheat crop as it had higher relative density (72.42%) as compared to other weeds *Phalaris minor* (22.08%) and *Avena ludoviciana*. However, *Echinochloa colona* was only the major weed in greengram having 100% relative density. It was found that rotational application of chlorimuron + metsulfuron-methyl 4.0 g/ha first year and bispyribac 25 g/ha during second year in rice and clodinafop 60 g/ha + 2, 4-D 0.5 kg/ha during first year and mesosulfuron + iodosulfuron-methyl 12 + 2.4 g/ha as post-emergence during second year after conventional tillage in rice and wheat, respectively and zero tillage in mungbean gave effective control of weeds in rice-wheat-mungbean cropping system. However, rotational application of herbicides after zero tillage in all component crops in absence of previous crop residues under had maximum system productivity *i.e.*, 18.38 t/ha.

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Bioefficacy of new generation post-emergence herbicides and their sequential application with pre-emergence herbicides on performance of maize

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Controlling of weeds in maize during the critical period assumes great importance for realizing its higher yield. Though hand weeding is effective, it is highly expensive and time consuming. Chemical weed control being cost effective and less labour intensive is recommended to overcome this constraint. There are very few herbicide options available for weed control in maize in India. Currently, herbicides used for control of weeds include pre-emergence application of atrazine, simazine, pendimethalin, alachlor and post-emergence application of 2, 4-D. Therefore, new herbicides with broad spectrum weed control are highly essential for effective management of weeds with less residual toxicity. Hence, the present study is carried out to find out the bioefficacy of some new generation post-emergence herbicides and their combination with other chemicals and methods on growth and yield of maize. The experiment with nine treatments along with one control was laid out in a randomized block design with three replications was conducted at Agronomic main research farm on *Rabi* 2016. The soil of the experimental plot was sandy loam with medium N, P, K status. The treatments were imposed to test bioefficacy new generation post-emergence herbicide (tembotrione, topramezone) alone or in combination with pre-emergence herbicide (pendimethalin, atrazine) on weed dynamics, growth and yield of maize. The important weeds observed were *Cyanodon dactylon, Digitaria sanguinalis, Eleusine indica, Dactyloctenium aegyptium, Sporobolus diander* under grass category. *Cyperus rotundus, Cyperus iria* under sedge category. *Amaranthus viridis, Cleome viscosa, Cleome rutidosperma, Celosia argentea, Melochia chorchorifolia, Spilanthes acmella* and *Phyllanthus niruri* were among broad-leaved category. From the result it was concluded that pre-emergence application of pendimethalin (1 kg/ha) *fb* post-emergence application of either topramezone (25 g/ha) or tembotrione (115 g/ha) at 40 DAS found to be the best, effective and economic method of weed control in *rabi* maize. The treatment resulted in higher fresh cob yield of (36.28 t/ha) was recorded in pre-emergence application of pendimethalin (1 kg/ha) *fb* topramezone (25 g/ha) at 40 DAS treatment. Treatment such as pre-emergence application of pendimethalin (1 kg/ha) *fb* tembotrione (115 g/ha) at 40 DAS, pre-emergence application of pendimethalin (1 kg/ha) *fb* 1 HW at 40 DAS, pre-emergence application of atrazine (1 kg/ha) *fb* 1 HW at 40 DAS were next in order. Similar trend as that of fresh cob yield was observed in fresh kernel yield and green fodder yield. Highest net return (` 251485/ha) was obtained from pre-emergence application of pendimethalin (1 kg/ha) *fb* topramezone (25 g/ha) at 40 DAS with highest (3.26) benefit cost ratio (B:C).

Efficacy of pre- and post-emergence herbicides in maize

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The present investigation "Efficacy of pre and post-emergence herbicides in maize (*Zea mays* L.)" was carried out at the field of Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *Summer* 2015. In the present investigation chemical weed management practices *i.e.* herbicides *viz*; pendimethalin, atrazine, 2, 4-D sodium salt, and atrazine were used alone and in combination *i.e.* 2, 4-D sodium salt 0.80 kg/ha PoE 30 DAS, 2, 4-D sodium salt 1.20 kg/ha PoE 30 DAS, atrazine 1 kg/ha PE, atrazine 0.50 kg *fb* 2, 4-D 0.50 kg/ha PoE 30 DAS, pendimethalin 1 kg/ha PE and in combination with atrazine and pendimethalin *i.e.* atrazine 0.50 kg/ha + pendimethalin 0.50 kg/ha PE (tank mix) with weed free and weedy check were studied.

Atrazine 1.0 kg/ha PE recorded lowest monocot and dicot weeds, total weed count and weed dry weight at early stages of crop growth up to 30 DAS. Subsequently at 40 DAS after sowing up to at harvest, the total weed count and weed dry weight were lower in atrazine 0.50 kg/ha *fb* 2, 4-D 0.50 kg/ha PoE 30 DAS. The treatment weedy check showed highest monocot and dicot weeds infestation and weed dry weight. Maximum weed control efficiency at 30 DAS was obtained with treatment atrazine 1 kg/ha PE. At 40 DAS up to at harvest higher weed control efficiency was observed in treatment atrazine 0.50 kg/ha *fb* 2, 4-D 0.50 kg/ha PoE 30 DAS. Lowest weed index was recorded in treatment atrazine 0.50 kg/ha *fb* 2, 4-D 0.50 kg/ha PoE 30 DAS and highest weed index was obtained with treatment weedy check.

Plant height of maize crop was improved with atrazine 0.50 kg/ha *fb* 2, 4-D 0.50 kg/ha PoE 30 DAS, while treatment weedy check recorded minimum plant height. Whereas, maximum number of leaves per plant was recorded in atrazine 0.50 kg/ha *fb* 2, 4-D 0.50 kg/ha PoE 30 DAS over treatment weedy check. Plant dry matter initially (30 DAS) was higher in atrazine 1 kg/ha PE, later growth stages treatment atrazine 0.50 kg *fb* 2, 4-D 0.50 kg/ha PoE 30 DAS recorded highest dry matter. Lowest plant dry matter was recorded in weedy check. Yield attributes *i.e.* no. of grain per cob, cob weight, grain weight per cob, test weight were significantly higher in atrazine 0.50 kg/ha *fb* 2, 4-D 0.50 kg/ha PoE 30 DAS. The lower no. of grain per cob, cob weight, grain weight per cob and 100 seed weight was recorded in weedy check. Different weed management practices significantly improve the grain yield and stover yield. Weed free treatment registered highest grain yield (4.75 t/ha) which was followed by treatment atrazine 0.50 kg/ha *fb* 2, 4-D 0.50 kg/ha PoE 30 DAS (4.12 t/ha). Weedy check treatment recorded lowest grain yield *i.e.* (2.02 t/ha). Treatment atrazine 0.50 kg/ha *fb* 2, 4-D 0.50 kg/ha PoE 30 DAS recorded highest B:C ratio (3.11), while minimum B:C ratio (1.82) was observed in weedy check.

Bioefficacy of markclodina, a brand of clodinafop against weeds in wheat

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Wheat (*Triticum aestivum* L.) is the second most important food grains next to rice in India in terms of area and production being used as a staple diet. Isoproturon was the most popular herbicide for weed control in wheat. However, its sub optimum and continuous use led to development of resistance particularly in *Phalaris minor* in some parts of Indo-gangetic plains. In order to tackle the resistance problem, some alternative herbicides and their brands need to be tested for weed control in irrigated wheat. Clodinafop is one such herbicide now widely used in wheat growing areas of India. It has been also evaluated and recommended for the control of major grassy weeds in wheat under conditions of Himachal Pradesh. Six treatments, *viz.* markclodina 0.060 kg/ha, clodinafop propargyl 0.060 kg/ha (market sample), pendimethalin 1.0 kg/ha, isoproturon 1.0 kg + 2, 4-D 0.5 kg/ha, hand weeding at 30 and 60 days after sowing (DAS) and weedy check were tested in randomized block design (RBD) with three replications. The trial was conducted at Palampur during *Rabi* 2015-16 and resulted were demonstrated at farmers field during *Rabi* 2016-17.

Agro climatically, the experimental site falls in the mid hills sub humid zone of the state. The weather parameters were conducive for the growth and development of wheat crop. Mean monthly maximum temperature (30.5 °C) during crop season was in May and minimum (3.7 °C) in January. The soil of the experimental field was silty clay loam in texture, medium in organic carbon (0.67%), acidic in reaction (pH 5.7).

Avena ludoviciana (34.3%) and *Phalaris minor* (25.3%) were the most dominating grassy weeds. New test herbicide markclodina had better efficacy in controlling *Phalaris minor*, *Avena fatua* and *Lolium temulentum* as evidenced from significantly less number of weeds at all the stages of observations. Post-emergence application of markclodina remains at par with the clodinafop propargyl in reducing weed dry weight of *Avena ludoviciana* and *Phalaris minor*. Hand weeding twice reduces dry weight of *Lolium temulentum* and *Coronopus didymus* significantly which was followed by post-emergence application of markclodina. Highest weed control efficiency 100% at 60 DAS was recorded with hand weeding twice and 80.5% at 90 DAS was recorded with post-emergence application of markclodina 0.060 kg/ha. The application of markclodina 0.06 kg/ha remaining at par with clodinofop propargyl (market sample) 0.060 kg/ha, isoproturon 1.0 + 2, 4-D 0.5 kg/ha produced significantly higher grain yield over other treatments. The magnitude of increase in yield due to markclodina over weedy check was 68.9%. Highest MBCR was recorded with post-emergence application of markclodina *fb* clodinofop propargyl. Field demonstrations on the performance of markclodina at different locations in district Hamirpur of Himachal Pradesh indicated upto 19.7% increase in grain yield over control.

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Weed management options for spring sweet corn

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A field experiment was conducted during *spring* season of 2017 in D6 block of the N.E.B.C.R.C. of G.B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand) with objectives to study the bioefficacy of new generation herbicides against complex weed flora and phytotoxicity on crop if any, to study the effects of different cultural and chemical control measures alone and their combinations on weeds, crop growth and yield and to find out the best method of weed management on the basis of crop yield and economic parameters.

The soil on the experimental site was sandy loam, neutral in pH with high organic carbon (0.79%), medium available nitrogen (314.3 kg/ha), phosphorus (19.8 kg/ha) and potassium (220.3 kg/ha). Sweet corn variety *'Sugar 75'* was sown on 21st February, 2017 and harvested on 2nd June, 2017. The experiment was laid out in a randomized block design with three replications and twelve treatments *viz.* intercropping with mung bean, paddy straw mulching 5 t/ha, atrazine 1000 g/ha, halosulfuron-methyl 90 g/ha, tembotrione 120 g/ha, atrazine 1000 g/ha with paddy straw mulching, atrazine 1000 g/ha followed by halosulfuron-methyl 90 g/ha, atrazine 1000 g/ha followed by tembotrione 120 g/ha, atrazine at 1000 g/ha followed by one hand weeding at 40 DAS, twice hand weeding at 20 and 40 DAS, weed free and weedy check.

The major weeds infesting the experimental field were *Cynodon dactylon*, *Echinochloa colona* among grasses, *Alternanthera sessilis*, *Celosia argentea* among broad-leaf weeds and *Cyperus rotundus* among sedges. Pre-emergence application of atrazine 1000 g/ha followed by post-emergence application of halosulfuron-methyl 90 g/ha was the most effective treatment in reducing weed density and twice hand weeding at 20 and 40 DAS was found most effective in reducing weed dry matter accumulation as compared to other treatments.

All the weed control treatments significantly influenced the yield and yield attributing characters. Highest green cob yield was obtained with twice hand weeding at 20 and 40 DAS (15.46 t/ha) which was at par with pre-emergence application of atrazine 1000 g/ha followed by post-emergence application of tembotrione 120 g/ha (15.31 t/ha) among the weed control treatments. The highest net return and B:C ratio was recorded with pre-emergence application of atrazine 1000 g/ha followed by post-emergence application of tembotrione 120 g/ha which was followed by twice hand weeding at 20 and 40 DAS. Pre-emergence application of atrazine 1000 g/ha followed by application of tembotrione 120 g/ha was found best among the herbicidal treatments. Twice hand weeding at 20 and 40 DAS was found comparable with pre-emergence application of atrazine 1000 g/ha followed by post-emergence application of tembotrione 120 g/ha and can be used as an alternative subjected to availability of labourers.

Residue management in no-till and raised beds influences the weed dynamics and productivity of *Kharif* maize (*Zea mays* L.)

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Weeds cause serious yield losses in crops due to their tremendous capacity of resource uptake, so their management is crucial for the development of sustainable crop production. Managing weeds is most critical for maximize yield and needs effective management to realize higher yields. Hence, in this regard a field experiment was conducted at CCS HAU, Regional Research Station, Karnal, Haryana during *Kharif* 2015. Infestation of major grassy weeds (*Dactyloctenium aegyptium, Brachiaria reptans, Eragrostis tenella*), broad-leaf weeds (*Portulaca oleracea*, *Ammania baccifera*) and sedges (*Cyperus rotundus*) along with some other broad-leaf weeds (BLW) were found in experimental plots. Two planting methods *viz*. zero tillage (ZT) and raised beds (RB) each with and without wheat residues were evaluated across three maize hybrids (HQPM-1, HM-4 and HM-10) and two weed control treatments *viz.* Atrazine 750 g/ha pre-emergence (PRE) followed by (*fb*) 1 hand weeding (HW) at 30 days after sowing (DAS) and unweeded check in a split plot design. Atrazine was applied as PRE spray to soil surface as per treatments at 0-3 DAS with flat fan nozzle using a spray volume of 500 L water/ha.

Among planting methods, lowest dry weight of grassy weeds (13.51 g/m^2) and sedges (1.73 g/m^2) were recorded under zero tillage with residue (ZT + R) *fb* raised bed with residue (RB + R), zero tillage without residue (ZT-R) and highest in raised bed without residue (RB-R), however, grassy weeds significantly at par in ZT + R and RB + R. Lowest dry weight of BLW (2.07 g/m^2) was recorded under ZT + R *fb* RB + R, RB-R and highest in ZT-R at 40 DAS. Maximum grain yield (7.32 t/ha) and net returns (` 59958/ha) were recorded under ZT + R than other methods. However, grain yield in ZT + R and RB + R statistically at par with each other. Similarly, residue retention was better than without residue in respect of all the above parameters.

Lowest dry weight of grassy weeds (14.42 g/m^2) and sedges (2.50 g/m^2) were recorded under HM-10 at 40 DAS, but in grassy weeds, HM-4 and HM-10 were at par with each other at 40 DAS. Lowest dry weight of BLW (1.62 g/m^2) at 40 DAS and; maximum grain yield (7.04 t/ha) and net returns (` 58749/ha) were found under HM-4 as compared to HM-10 and HQPM-1. In general, biomass of weeds was lowest under HM-10 *fb* HM-4 and HQPM-1. Atrazine 750 g/ha (PRE) *fb* 1 HW at 30 DAS attained lowest dry weight of weeds (grassy weeds, BLW and sedges) and; higher grain yield (7.70 t/ha) and net returns (` 66593/ha) than unweeded check at 40 DAS.

Conclusively, ZT + R recorded minimum dry weight of grassy weeds, BLW and sedges. In general, maize hybrid (HM-4 and HM-10) and atrazine 750 g/ha (PRE) *fb* 1 HW at 30 DAS recorded lower dry weight of weeds and higher productivity. Therefore, maize sown in ZT with wheat residue as mulch found an effective control of weeds with higher productivity.

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Efficacy of metribuzin based herbicide mixtures for weed management in wheat under semi-arid conditions of Haryana

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Wheat (*Triticum aestivum*) is the world's most widely cultivated food crop with high nutritive value and it is second important staple food crop after rice in India. Among the annual agricultural losses caused by all the pests in wheat in India, weeds account for 45 per cent. Therefore, weed competition is one of the most important constraints in crop production. Cultivars of several crops including winter wheat differ considerably in their tolerance to metribuzin and differential varietal sensitivity to fenoxaprop + metribuzin has also been reported. So, a field experiment was conducted during 2014-15 and 2015-16 at Research Farm, Department of Agronomy, CCS Haryana Agricultural University, Hisar, Haryana (India) to study the efficacy of metribuzin based herbicide mixtures for weed management in wheat varieties. The experiment was carried out in split-plot design keeping five wheat varieties, *viz.* WH 1105, HD 2967, DPW 621-50, WH 1124 and DBW 17 in main plots and six weed management practices in sub plots, *viz.* metribuzin (210 g/ha), metribuzin + clodinafop (150 + 45 g/ha), metribuzin + pinoxaden (150 + 40 g/ha), metribuzin + fenoxaprop (150 + 100 g/ha), weed free and weedy check in sub plots with three replications. All the herbicide treatments were applied at 35 days after sowing of wheat. The wheat varieties did not affect the weed density and weed dry matter accumulation during both the years. Among the herbicide treatments, the mixture of metribuzin and fenoxaprop (150 + 100 g/ha) resulted in maximum control of grassy weeds and it was statistically at par with metribuzin + pinoxaden (150 + 40 g/ha) and metribuzin + clodinafop (150 + 45 g/ha) during both the years. Sole application of metribuzin (210 g/ha) was better than weedy check in controlling grassy weeds, but was inferior to mixtures of metribuzin with rest of the herbicides. In case of density of broad-leaf weeds, application of metribuzin (210 g/ha) was found to be best effective among all the herbicidal treatments during both the years and it differed significantly from all the herbicidal treatments as well as weedy check. Combination of metribuzin + fenoxaprop (150 + 100 g/ha), metribuzin + pinoxaden (150 + 40 g/ha) and metribuzin + clodinafop (150 + 45 g/ha) resulted in statistically at par population of broad-leaf weeds. Combination of metribuzin with fenoxaprop resulted in highest reduction in dry matter accumulation by grassy and total weeds and but it was at par with metribuzin in combination with pinoxaden and clodinafop. Metribuzin, when applied alone (210 g/ha) resulted in significant decrease in dry matter accumulated by broad-leaf weeds in comparison to weedy check and other herbicidal treatments. Wheat variety WH 1105 produced maximum grain yield and it remained at par with WH 2967 and DPW 621-50 during both the years. Among herbicidal treatments, mixture of metribuzin with fenoxaprop remained statistically superior to weedy check plots as well as plots where metribuzin was applied alone in terms of wheat grain yield.

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Problem weeds in major crops and cropping system in Madhya Pradesh, Arunachal Pradesh, Assam and Bihar

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Weeds in general account for 30% loss in agricultural productivity besides they have detrimental effect on biodiversity, environment and well being of human beings, livestock and aquatic life. Research on the status of different kinds of weeds in varied agro-climatic conditions and their control measures in cropped, non-cropped areas and aquatic bodies is very much essential to boost our agricultural production and improve upon the quality of life. *Phalaris minor, Cyperus rotundus, Cynodon dactylon, Commelina benghalensis, Digera muricata* are major weeds in the major crops grown in Madhya Pradesh namely paddy, wheat, maize, jowar, gram, tur, urd, moong, soybean, groundnut and mustard. Commercial crops like cotton and sugarcane are also grown in a considerable area. Horticultural crops like potato, onion, garlic, along with fruit crops like papaya, banana, orange, mango and grapes are also grown besides medicinal and narcotic crops to some extent. Ginger and beetelvine are grown in the Bundelkhand region. Other important crops of this region are coriander, potato, sugarcane, turmeric, colocasia, sweet potato etc. Horticultural crops like fruits, vegetables, condiments and spices are also grown in this region. In Malwa plateau zone, sorghum, maize and soybean are the major crops in *Kharif* and chickpea and wheat are the major crops of *Rabi*. In Jhabua hill region, maize occupies the largest area followed by sorghum. Cultivation of cotton is limited to black soils. In Arunachal Pradesh dominance of weeds *Eleusine indica*, *Cynodon dactylon*, *Oxalis latifolia*, *Cyperus* sp, *Digitaria sanguinalis* in field crops- rice, maize, fingermillet, mustard/toria, til, blackgram, buckwheat *etc.* Vegetable crops- okra, cole crops, vegetable pea, cowpea, beans, tomato, potato. Spices- ginger, turmeric. Cropping pattern- rice/til- mustard/ buckwheat, rice- beans/potato/cabbage/cauliflower/tomato, maize- potato/beans/green pea, maize-black gram and ginger/turmeric-fallow. *Borreria articularis, Cynodon dactylon, Echinochloa crus-galli, Eleusine indica, Panicum repnes* are dominated weeds in Assam state where main crops are wheat, blackgram, greengram, pea and lentil while potato, cucumbers, colocasia and cole are the main vegetable crops. Sugarcane, jute, ramie and oil seeds *viz.*, rape and mustard, sesamum *etc.* are the important commercial crops grown. Banana, pineapple, areca nut, coconut, citrus, papaya and litchi are the major horticultural crops. Rice-rice, rice-boro rice, rice-mustard/rapeseed, rice-vegetables and grrengram/blackgram are common cropping systems in winter. *Cynodon dactylon, Phalaris minor, Echinochloa colona, Cyperus rotundus, Chenopodium album* are weeds in diverse agro-climatic conditions prevailing in the state enable it to grow a multitude of crops almost of all types *viz.*, cereals, pulses, oilseeds, millets, fibres, vegetables, fruits and spices. However, the basic feature of the cropping systems in Bihar is that it is cereal-based with rice, maize and wheat being the main cereals. Under irrigated situations, rice-wheat or rice-maize are the most important crop sequences. Jute-rice and jute-rice-wheat systems are being followed extensively in the district of Katihar, Purnea and Madhepura. Among the cash crops, tobacco and chillies are most important apart from sugarcane. Mango, litchi and banana are the horticultural crops that are extensively grown. Ginger, turmeric, coriander and mangraila in spices are the other important crops of this region.

Yield and economics of fenugreek (*Trigonella foenum-graecum* L.) under weed management practices and their residual effect on succeeding summer fodder maize

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A field experiment was conducted at Instructional farm, Rajasthan College of Agriculture, MPUAT, Udaipur during *Rabi* 2016-17 and 2017-18 to study the weed flora, growth, yield and economics of fenugreek. The experiment consists of thirteen weed management treatments assigned to main plot comprising imazethapyr (70 g/ha and 70 g/ha *fb* hoeing at 40 DAS), imazethapyr 50 g/ha PoE at 2-4 leaf stage, imazethapyr + imazamox (RM) 50 and 60 g/ha at 2-4 leaf stage), pendimethalin 750 g/ha PE, oxyfluorfen (120, 150 g/ha and 120 g/ha *fb* hoeing at harvest), oxadiargyl (100 g/ha and 100 g/ha *fb* hoeing at 40 DAS) including weed free and weedy check and levels of vermicompost in sub plot, *viz*. control and 5 t/ha. The experiment was laid out in split plot design with three replications. The soils of experimental field was clay loam in texture slightly, alkaline in reaction, medium in organic carbon, available nitrogen, available phosphorus and high in available potassium. Fenugreek variety '*RMT-305*' was sown at 30 cm distance with 25 kg/ha seed rate and recommended dose of fertilizers *i.e*. 40:40, N:P_2O_5 kg/ha was applied as basal dose through urea and DAP. After calibration of sprayer, water volume used was 650 litres for PE and 500 litres for PoE with flat fan nozzle. The pooled of two years results revealed that pre-emergence application of oxadiargyl 100 g/ha *fb* hoeing at 40 DAS recorded significantly higher weed control efficiency (82.3%), plant height (59.83 cm), number of branches (6.09), number of pods (44.86), number of seeds/pod (17.33), seed weight (9.05 g/plant). The same treatment recorded higher seed (2.82 t/ha), haulm (6.70 t/ha) and biological yield (9.52 t/ha) and harvest index (29.7%) which were at par with weed free treatment. Significantly higher net returns (` 98158/ha) and B: C ratio (2.63) was obtained from oxadiargyl 100 g/ha *fb* hoeing at 40 DAS. Residual effect of herbicides used for fenugreek did not showed any phytotoxic effect on succeeding summer fodder maize in terms of visual phytotoxicity rating at various growth stages of maize, weed flora, dry matter of weeds as well as crop at 30 DAS and green fodder yield of summer fodder maize.

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Weeds and weed management in Kymore plateau and Satpura hills of Madhya Pradesh

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India with highly diverse agriculture and farming systems are beset with different types of weed problems in Indian agricultural. Weed is a silent killer of crop and productivity goes down making the farmers baffled. Weeds are unwanted and undesirable plants that interfere with the utilization of land and water resources that adversely affect crop production and weeds cause 10-70% crop yield losses besides impairing product quality and causing health (pathogens serwied in weeds) and environmental hazards. Invasive alien weeds are a major constraint to agriculture, forestry and aquatic environment. Weeds are crop specific (wheat in wheat) affecting crop production, quality of product and income of farmers. Effective weed management practices include those that reduce the potential for weeds to adversely impact crop growth and yield. These practices often allow the crop to utilize all available resources necessary to achieve its yield potential. Weeds require many of the same resources for growth as crop plants, and any resource utilized by the weed is unavailable for use by the crop. Traditionally, weed control in India has been largely dependent on manual weeding. However, increased labour scarcity and costs are encouraging farmers to adopt labour and cost saving options. These include herbicides whose market grew at an annual rate of 15%. The continuous application of isoproturon coupled with mono-cropping rotation of rice-wheat has led to the evolution of resistance in *Phalaris minor*. In the northern part of India efforts to manage herbicide resistance have led to the adoption of conservation agriculture in the rice-wheat cropping system, as a component of IWM. Herbicides applied alone or in combinations, have been regarded as essential tools in the effective management of weeds in different-ecosystems. IWM, which includes preventative, mechanical, cultural, chemical and biological methods, is advocated in crop production systems as well as aquatic and forest ecosystems. Newer weed management approaches must be developed considering the threat of HR weeds appearance in addition to the recurrence and persistence of weeds and the need to bring down weed management costs to enhance profit for farmers while protecting the environment. This article explores the scope of sustainable weed management, growing concerns over herbicide resistance, environmental and health hazards of pesticides including herbicides and declining profitability are the major challenges of 'high input' agriculture. To facilitate for development of ecologically based alternative methods for weed management that will support crop production systems, which require less tillage, herbicide and other inputs. To accomplish the research efforts must be radically expanded in crop ecology and in the development of ecologically based technologies for weed management.

Striga hermonthica control and maize (*Zea mays*) yield following natural and planted fallows at Minna, Nigeria

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The witchweed (*Striga* spp.) is endemic to sub-saharan Africa thereby contributing greatly to food insecurity in the region as it causes heavy yield losses to legume and cereal crops. In this study, *Striga hermonthica* control and maize (*Zea mays* L.) grain yield were evaluated on a naturally *Striga* infested field on continuous cropping or following one and two years of natural and planted fallows. The seeds of the planted fallows: *Hyptis suaveolens* (L.) Poit (3 kg/ha) and *Desmodium intortum* (Mill.) Urb. (3.3 kg/ha) were mixed with 20 kg of sand while *Senna obtusifolia* (L.) (25 kg/ha) was mixed with 25 kg of sand and sown by broadcast. Ridges were constructed 75 cm inter-row with a hand-held hoe in the first week of July of each year of study. The maize variety Oba W-98 was sown at three seeds per hill at 50 cm intra-row and thinned to two seedlings per stand at two weeks after sowing. The experiment was arranged in randomized complete block design with three replicates. The study was carried out from 2013 to 2015 at Minna (9.37^{o} N; 6.33^{o}E) in southern Guinea savanna of Nigeria. *H. suaveolens* consistently added more organic carbon to the soil after one or two years fallow than all other species. Soil total N was depleted in all the treatments at the end of one year, but increased at the end of two years fallow, being the highest in *S. obtusifolia* plot. Also, *H. suaveolens* contributed more P to the soil at the end of two years fallow than all other treatments. *Striga* shoot emergence was not affected following one year fallow, however it was significantly delayed following two years of planted fallow compared to continuous cropping. Furthermore, the use of *D. intortum* although similar to other planted fallow species, significantly delayed *S. hermonthica* shoot emergence compared to natural fallow and continuous cropping. *Striga* shoot densities following all the fallow treatments were similar, but significantly lower than the continuously cropped treatment in both years. Grain yield was highest in maize following one and two years of *S. obtusifolia* fallow, although it was similar to those of other fallows in the first year and *D. intortum* two years fallow only. It is recommended that *S. hermonthica* sick land be fallowed for a minimum of two years with *S. obtusifolia* or *D. intortum* to reduce *Striga* infestation and to increase maize grain yield as part of integrated management strategy.

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Effective weed management by mechanical tools

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Weeds are the unwanted plants in cropping conditions, which causes economic and social harm to the farmers under certain circumstances. Weeds alone cause a loss of total agricultural production up to 37%, if not managed properly. Weeding is one of the most important farm operations in agriculture and it is laborious and costliest practices. It accounts for about 25% of the total labour requirement (900–1200 man-h/ha) during a cultivation season and involves 1/3 rd of cultivation cost. However, the labour requirement for weeding depends on weed flora, weed intensity, time of weeding, soil moisture and efficiency of the worker. Often several weeding are necessary to keep the crop weed free.

Weeding in developing countries like India is performed manually with traditional hand tools like khurpi and spade. But these tools are used in squating and bending postures. In these postures, the energy consumption for a given load is 30-50% more as compared to standing or sitting posture. Traditional weeders are used in undesirable postures, which involve repetitive movement of body parts cause's musculoskeletal disorders. These problems can be overcome by using the improved mechanical tools.

Mechanical weed control involves manually operated tools like khurpi, spade, grubber, wheel hoe, peg tooth weeder, star weeder, cono weeder; animal operated implements like single blade and multi blade hoes and power operated weeders like tractor/power tiller operated and self propelled weeder. Weeding by manually operated weeders is having a higher weeding efficiency; the efficiency can be obtained in the range of 80 to 95 per cent. However, there field capacity is lower compared to animal and powered weeders. The data compiled by DWR through AICRP on Weed Management have shown that, weed control through different mechanized weeding operations have given significantly more yield over farmer's practice, with nearly one-third saving in the cost on weed control. Hence, efficient and effective methods of weed control are the need of the hour as they invariably ensure higher crop productivity. The improved weeding tools and implements includes, ergonomically refined hand weeding tools and wheel hoes, brush cutters, power weeders, tractor operated weeders *etc*.

Bio-efficacy of pinoxaden against weeds in wheat and their residual effect on baby corn

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A field experiment was conducted at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) on sandy loam soil which was low in nitrogen and medium in phosphorus and potassium during winter (*Rabi*) season of 2017-18 to study the bio efficiency of pinoxaden for the controlling of complex weed flora in wheat (*Triticum aestivum* L.) and also its residual effect on baby corn. The treatment comprised of seven treatments *viz.* pinoxaden 35 g/ha, pinoxaden 40 g/ha, pinoxaden 45 g/ha, sulfosulfuron 25 g/ha, hand weeding (at 20 and 40 DAS) and untreated control (weedy check) in a RBD. Results revealed that the dominant grass weeds like *Phalaris minor* Retz, *Avena ludoviciana* were effectively controlled during the crop period by post emergence application of pinoxaden at 30 DAS but did not significantly influenced density of *Anagalis arvensis*, *Melilotus indicus*, *Polygonum plebeium*, *Cynodon dactylon*, *Cyperus rotundus* and *Parthenium hysterophorus*. The yield attributes and yield of grain and straw of wheat (*HD-2967*) were recorded higher under post-emergence application of pinoxaden 45 g/ha and the magnitude of increase in grain and straw yield over untreated control (weedy check) was 15.3 and 9.9%, respectively. Residue effect of herbicidal treatment on baby corn did not show marked variation in per cent crop germination, plant population, number of cobs/plant, baby corn weight, baby corn length, cob: baby corn girth and baby corn ratio of baby corn. However, application of the herbicides to wheat crop significantly influenced on plant height, baby cob weight, total baby cob yield, total baby corn yield and green fodder yield of succeeding baby corn crop. Post-emergence application of pinoxaden at 35 g/ha to wheat exhibited significantly higher plant height, baby cob weight, total baby cob yield, total baby corn yield and green fodder yield which was statistically at par with application of pinoxaden either at 40 or 45 g/ha.

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Herbicide resistance in India, causes and management options

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Going by the losses caused by weeds, herbicide use has to increase in the future to realise yield potential and increased production to feed 1.3 billion mouths in India. Average annual consumption of herbicides in many advance countries range from 675 to 1350 g/ha (Japan being highest 5000 g/ha) compared to only 40 g/ha in India. Though in the recent years herbicide use is growing at 15% and by 2022 it is projected that herbicide market will be around 1.0 bn US$ in India. On the other hand continuous use of herbicides with similar site of action have resulted in weed flora shift and evolution of resistant weeds particularly in wheat in North-West India which is the grain bowl of the country. Herbicides resistance reported in the 1990s against *Phalaris minor* has also been confirmed to several herbicides against *P. minor* as well as in *Avena ludoviciana*, *Rumex dentatus*, *Polypogon monspeliensis* and *Chenopodium album*, whereas problems of lower efficacy at farmers' fields have also been reported in *R. spinosus* and *C. murale*. As of today, there is no registered herbicide in India for use in wheat that has no problems with one or other resistant weed species. This will not only adversely affect crop yield, but will also inflated cost of weed management. Isoproturon resistance was characterized by enhanced metabolism by cytochrome P450 monooxygenase enzymes or its isozymes, though target site mutation was also reported in *P. minor* to clodinafop-propargyl. Having more than one resistance mechanisms is a sure shot to make any new herbicide ineffective after few applications and that may be a major challenge to new herbicide chemistries as some herbicides have shown reduced efficacy against multiple herbicide resistant weed species without even their field use. This warrants radical change in weed management philosophies to lower the build-up of resistance and improve weed control efficiency using all the possible tools available to us in an integrated weed management system. Climate change will also be a double edged sword to lower herbicide efficacy due to moisture stress and increased temperature in India. Also this will change weeds emergence pattern and their biology making it more challenging to efficiently manage them. Though there is no new chemistry as of today to take care of all the infesting troublesome weeds, but even if there is one, that too may not suffice alone in the future. Combating weeds will require precision application of herbicides, their selection, more than one application and even multiple herbicides mixture or sequential use, their rotation along with crop rotation and intelligent agronomic interventions. Weed seeds separation at threshing and their destruction with enhanced machinery, robotics for weeds removal, and microbial herbicides will be employed in the future to lower weeds menace.

Management of complex weed flora through herbicide combinations in irrigated wheat

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Wheat (*Triticum aestivum* L.) is one of the most important staple food crop cultivated in almost all the countries in the world. Wheat is the second most important grain crop of India after rice and thus crucial for the food security of the country. Wheat provides about 20% of total food calories for the human race. Wheat grain contains about 12.2% protein and the gluten in the grain provides the structural framework for the spongy, cellular texture of bread and bakery products. Wheat has a relatively high content of niacin and thiamine.

Wheat production in India is 93.50 million tonnes during 2015-16. The major wheat growing states in India are Uttar Pradesh, Punjab, Madhya Pradesh, Haryana, Rajasthan, Bihar and Gujarat. The average wheat productivity of India is 3.2 t/ha.

Wheat production is directly affected by several factors and one of the most limiting factor is infestation of weeds. Weed reduces the yield of wheat up to 50% based on the infestation. It is due to some dominated weed flora appearing at early stage and the luxuriant growth of weeds due to frequent irrigation and dominancy of monotony cropping system. Major dominant weed flora in Gujarat which affect the wheat yield are *Chenopodium murale*, *Chenopodium album*, *Phalaris minor, Avena fatua*, *Melilotus alba*, *Asphodelus tenuifolius, Eleusine indica* L., *Digeria arvensis* Forsk. and *Setaria tomentosa*. This weeds not only reduce the yield but also make the harvesting operation difficult. Manual removal of weeds in wheat crop is laborious, time-consuming and uneconomical due to higher rate of labour wages. Therefore, chemical control of weeds is the preferred option.

A field experiment was carried out during the *Rabi* 2017 at B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat), to manage complex weed flora through herbicide combinations in irrigated wheat cv.'*GW 451*'. Application of pendimethalin *fb* sulfosulfuron (500+18 g/ha, PE *fb* PoE) recorded lowest monocot weed density (9.33/m^2) and dry matter (14.73 g/m^2) at 80 DAS the same trend was observed at harvest and premix clodinafop + metsulfuron-methyl (60+4 g/ha) as post-emergence application gave lower dicot weed density (5.33/m^2) and dry matter (4.32 g/m^2). The highest weed control index was observed with premix clodinafop + metsulfuron-methyl (60+4 g/ha) followed by pendimethalin *fb* sulfosulfuron (500+18 g/ha, PE *fb* PoE), 98.08% and 92.63%, respectively. Higher grain yield was observed under pendimethalin *fb* sulfosulfuron (500+18 g/ha, PE *fb* PoE) (5.46 t/ha) followed by premix clodinafop + metsulfuron-methyl (60+4 g/ha) (5.40 t/ha) and hand weeding (5.30 t/ha). Whereas, higher straw yield was recorded with premix clodinafop + metsulfuron-methyl (60+4 g/ha) followed by hand weeding and pendimethalin *fb* sulfosulfuron (500+18 g/ha, PE *fb* PoE), 8.3 t/ha, 7.2 t/ha and 7.1 t/ha, respectively. Lowest grain (1.4 t/ha) and straw yields (4.9 t/ha) was observed under un-weeded control treatment. However, mesosulfuron + iodosulfuron (12+2.4 g/ha) PoE showed phytotoxicity on plant at 40 DAS.

Performance of wheat under the conservation agriculture at farmers' fields in Jabalpur, Madhya Pradesh

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Conservation agriculture (CA) involves minimum soil disturbance, permanent soil cover through crop residues or cover crops, and crop rotations for achieving higher productivity. CA has emerged as an effective strategy to enhance sustainable agriculture worldwide. CA has the potential to address the problems of natural resource degradation and environmental pollution, while enhancing system productivity. It is a resource-saving agricultural production system that aims to achieve production intensification and high yields while enhancing the natural resource base through compliance with good production practices of plant nutrition and pest management. CA is based on three principles; (i) minimal soil disturbance, (ii) soil cover with crop residues, and (iii) crop rotation. This study is based on the enhancing the production and productivity of wheat through intervention of need based technologies in two villages *viz;* Barouda and Umariya Choubey of Panagar block, Jabalpur Madhya Pradesh. This study was carried out under the 'Farmer FIRST programme'. Total of 25 farmers (25 farmers for ZT and 25 farmers for conventional practices) were selected randomly. The paper has compared the economics of wheat production with zero tillage (ZT) and conventional methods and assessed the contribution of technology and inputs to the increased productivity due to weed management under conservational agriculture. The results of the study revealed that the average yield of wheat under ZT was recorded 4.8±1.31 and 4.9±1.38 t/which was significantly higher than conventional method (4.1±1.83 and 4.0±2.88 t/ha) ha in Baroda and Umaria Choubey village respectively. The net income has been found higher in ZT method, due to increase the yield 17 and 23 per cent and lower cost of production compared to that in conventional method in Baroda and Umaria Choubey village, respectively. Benefit-cost ratio was found to be 3.48 and 3.54 in ZT, whereas 2.29 and 2.24 in Baroda and Umaria Choubey village, respectively, the B:C was 52 and 58 per cent higher in ZT methods compared to conventional methods in both villages. Weed density were recorded in zero tillage (ZT) and conventional methods *viz*; 15.8 and 15.49 and 29.20 and 26.24 per in Baroda and Umaria Choubey, respectively. Whereas dry weight 18.12, 13.98 and 24.66, 14.94 gm in Baroda and Umaria Choubey, respectively. The study has observed that ZT technology has potential to provide additional income to farmers and help in conservation of scarce resources. Despite several economic and environmental advantages, adoption of ZT technology has been limited and one major constraint identified is the difficulty in accessing a 'happy seeder machine' during peak sowing period. The study has suggested that ZT technology should be disseminated on a wider scale and availability of 'happy seeder machine' should be ensured at least through custom-hiring basis.

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Variety, sowing time and weed management influence on weed dynamics and yield of wheat under IGP area of India

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Wheat is the main food crop of the world as it contributes nearly 21% to the world's total food grains production. It is also staple food crop of developing countries and nearly 77 per cent of the total global wheat production is consumed in the developing countries. India is the second largest wheat producing country after China and it produces 12.7 percent of the world's wheat. Indo-Gangetic Plain (IGP) region produces approximately 75 per cent wheat of India. However, average productivity of wheat in the country is very low (3095 kg/ha) compared to Egypt (6400 kg/ha) and China (5300 kg/ha). Among the several yield limiting factors, severe weed infestation is most important. Infestation of weeds causes yield reduction up to 60% or sometime more depending upon the weed density and weed flora. Therefore, proper weed management is essential to ensure full potentiality of the crop. Various weed management practices such as cultural, mechanical and chemical have the ability to suppress the weeds up to great extent. Use of competitive crop genotypes and sowing time are the important cultural practices which can limit the weed infestation. Further more, manual weeding should not be promoted as it is tedious, labour intensive, expensive and non- availability of labour at the critical stage does not ensure effective weed management. Many pre-emergence and post-emergence herbicides are available for effective weed management in wheat crop, but sole dependence on a single method may not be able to manage all kind of weeds for a long time. Thus, integrated weed management can be very useful for the IGP region, because lot of weed infestation take place due to favourable agro-climatic condition of this region. Hence, a study was undertaken to evaluate the effect of variety, sowing time and weed management on the weed infestation and yield of wheat crop in IGP region.

A field experiment was conducted during 2014-15 to 2016-17 at the Indian Agricultural Research Institute, New Delhi, India (28°4' N latitude, 77°12' E longitude and 228.6 meters above MSL). Soil of the experimental field was sandy loam having pH 7.8, organic carbon 0.29%, available P 12.5 kg/ha and available K 246 kg/ha. The treatments consisted of two varieties (HD 2967 and WR 544), four sowing date (15 and 30 November, 15 and 30 December) and three weed management practices (weedy check, pendimethalin 0.75 kg/ha (pre-em) + one hand weeding at 30 DAS and pendimethalin 0.75 kg/ha (pre-em) + (sulfosulfuron 20 gm + metsulfuron 5 gm/ha at 30 DAS) were arranged in split split plot design with three replications. A uniform basal dose of 100 kg N, 60 kg $P_2O_5$and 40 kg K_2O/ha and herbicides were applied with spray volume of 500 litre/ha.

The experimental field was infested with broad leaved (68.2%) and grassy weeds (31.8%). Among the broad-leaved weed species *Coronopus didymus* (24.6%) and *Chenopodium murale* (17.3%) were recorded dominating weed species, whereas *Phalaris minor* (22.4%) and *Avena ludoviciana* (7.4%) recorded major grassy weed species. Varieties did not influence the density and dry weight of weeds. However, Variety 'HD 2967' recorded 11.6% lower average dry weight of weeds compared to WR 544. Due to the higher tillers and plant height characteristics of 'HD 2967', the most weeds were suppressed by this variety. Significant increase in the *Phalaris minor* population and dry weight was recorded on extending the sowing time from 15 November to 15-30 December, which might be owing to the availability of optimum temperature (10-20 ^{0}C) needed for the proper germination of *Phalaris minor.* On the contrary, owing to the suitability of temperature significant decrease in density and dry weight of broad-leaved weed species recorded with the crop sown on 15 and 30 November compared to delay in sowing (15-30 December). Weed management treatments significantly reduced density and biomass of weeds compared to weedy check. Application of pendimethalin 0.75 kg/ha (PE) with one hand weeding at 30 DAS caused maximum reduction of density and biomass of weeds and being at par with the application of pendimethalin 0.75 kg/ha (PE) + (sulfasulfuron 20 gm + metsulfuron 5 gm/ha at 30 DAS) recorded significantly lower over weedy check. The maximum mean grain yield (4.18 t/ha) and net returns was recorded with wheat variety '*HD2967*', but remained statistically at par with '*WR 544*'. Among the sowing date, crop sown on 15 November resulted in maximum increase (24.5%) in grain yield over crop sown on 30 December followed by 15 December (13.8%). However, no significant difference was observed between the crop sown on 15 and 30 November. The maximum net returns (` 49261/ha) was obtained with crop sown on 15 November followed by 30 November (` 46340/ha), whereas crop sown on 30 December could fetched only ` 32448/ha as net returns. As regards to the weed management practices, integrated application of 0.75 kg/ha +one hand weeding at 30 DAS produced the highest grain yield (4.74 t/ha) followed by pendimethalin 0.75 kg/ha (pre-em) + (sulfosulfuron 20 gm + metsulfuron 5 gm/ha at 30 DAS). However, lowest grain yield (3.16 t/ha) was recorded under weedy check. Maximum net returns (` 49808/ha) were also obtained with the application of 0.75 kg/ha + one hand weeding at 30 DAS (` 35477/ha).

It was concluded that sowing of wheat variety '*HD 2967*' on 15 November alongwith the pre-emergence application of pendimethalin 0.75 kg/ha followed by one hand weeding at 30 DAS or combined application of sulfosulfuron 20 gm + metsulfuron 5 gm/ha at 30 DAS found to be effective for controlling the weeds as well as obtaining higher grain yield and net returns with wheat crop under IGP area of India. Delaying the sowing of wheat was more effective for reducing *Phalaris minor* infestation.

Theme 8

Weed management in pulses and oilseeds crops

Tillage and weed management in soybean under conservation agriculture

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Conservation tillage is an important component of low input sustainable agricultural system. It is a resource management strategy aimed at reducing dependence on energy based inputs. Conservation tillage is not just a single concept, but a package of cultural practices that are specifically developed and adopted to conserve soil, water and nutrient resources, sustain high and satisfactory returns with minimum degradation to environment and preserve the natural resources. Minimum and zero- tillage practices have improved energy efficiency and reduced the production cost with greater productivity. The main principle of conservation agriculture is to cover the soil surface with mulch, which included crop residues, straw leaves etc. The experiment was conducted at the ICAR-DWR Jabalpur, during Kharif season 2017-18. Total weed density was lowest with ZTSR-ZTWR-ZTGR (35.3 no./m^2) followed by ZT-ZTWR-ZTGR (37.8 no./m^2), whereas, the highest weed density was recorded with CT-CT-CT (68.5 no./m^2). Similarly, weed dry biomass followed the trend of weed density, ZTSR-ZTWR-ZTGR recorded the lowest dry biomass (48.63 g/m^2) followed by ZT-ZTWR-ZTGR (52.72 g/m^2), whereas, the highest dry biomass in CT-CT-CT (109.56 g/m^2). The highest WCE was recorded with ZTSR-ZTWR-ZTGR (72.8%) followed by ZT-ZTWR-ZTGR (70.5%). Similarly, yield attributes and yield was also influenced by crop establishment method and maximum pod/plant was recorded in ZTSR-ZTWR-ZTGR followed by ZT-ZTWR-ZTGR. This helped to achieve better yield. During the season, the growth performance of soybean was exceedingly good, but, except number of pods/plant all the yield attributes were very poor *i.e.* smaller seed size, shriveled seeds, lower test weight and some pods unfilled grain, hence recorded considerably lower yield than previous year yield of soybean. However, the trend of seed yield was recorded the highest yield in ZTSR-ZTWR-ZTGR (773.3 kg/ha) followed by ZT-ZTWR-ZTGR (735.7 kg/ha), whereas, the lowest seed yield was recorded in CT-CT-CT (622.5 kg/ha). The straw yield of soybean was recorded highest with ZTSR-ZTWR-ZTGR (3.40 t/ha) followed by ZT-ZTWR-ZTGR (3.52 t/ha), whereas the lower straw yield harvested with CT-CT-CT (2.97 t/ha) and ZT-ZT-CT (2.98 t/ha). The lowest total weed density recorded with pre-emergence application of metribuzin *fb* one hand weeding (17.7 no./m^2) followed by pre-emergence application of pendimethalin *fb* imazethapyr (38.5 no./m^2). The highest weed density was recorded with weedy check (101.5 no./m^2). Weed dry biomass followed the trend of weed density and the lowest weed dry biomass with metribuzin *fb* hand weeding (23.5 g/m^2) followed by pendimethalin *fb* imazethapyr (43.0 g/m^2). The highest weed dry biomass recorded in weedy check (178.8 g/m^2). The highest WCE 87.4% was recorded with metribuzin fb hand weeding followed by pendimethalin *fb* imazethapyr over weedy check. It was also noticed that pre-mix application of imazethapyr + imazamox has considerably lower weed density and dry biomass and recorded 63.5% WCE over weedy check. Pods/plant was recorded the reverse trend of weed parameters and higher yield attributes obtained in metribuzin *fb* hand weeding (38.7 pods/plant) followed by pendimethalin *fb* imazethpyr (35.2 pods/plant) and lowest with weedy check (17.7 pods/plant). More pods/plant helped in obtaining higher seed and straw yield metribuzin fb hand weeding (866.8 and 4507.5 kg/ha, respectively) followed by pendimethalin *fb* imazethpyr (834.1and 4003.5 kg/ha, respectively).

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Weed flora of groundnut in Sirsa and Fatehabad districts of Haryana

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Groundnut (*Arachis hypogaea* L.) is one of the most important oilseed crop of India. Due to availability of high yielding varities, area under groundnut crop is increasingevery year in south-western parts of Haryana. Groundnut is a poor competitor with weeds and suffers heavily due to weeds from the early growth stage due to favourable environment for weeds to thrive. The critical period of weed competition is estimated to be 2-6 weeks after sowing and presence of weeds beyond this result in yield reductions by 30 to 90%. The magnitude of loss as a result of crop-weed competition depends upon type of weed species associated with the crop, their densities and duration of competition with the crop. Crop type and soil properties have greatest influence on the occurrence of weed species. The type of irrigation, cropping pattern, weed control measures and environmental factors also have a significant influence on the intensity and infestation of weeds. So, knowledge of weed species associated with crops in a region is therefore pivotal and necessary to plan and execute a sound and economical weed management schedule depending upon various factors affecting weed distribution in different areas. Keeping this in view, a weed survey was conducted in two districts *viz.* Sirsa and Fatehabad of Haryana during *Kharif* 2018 to study the floristic composition of weeds in groundnut, 14 fields were surveyed in Fatehebad and Sirsa districts of state during August, as this period depicted most appropriate representation of majority of weed species as the weeds have cumulative effects of all agronomic practices, soil type, fertilizer, irrigation and weed control measures adopted during initial crop growing period. Four observations on density of individual weeds were recorded per field at one spot by using a quadrate of (0.5 x 0.5 cm), 100 meters deep inside the field. Pooled average values of observations on weed density and relative frequency of individual weeds were calculated.

The survey revealed that a total of 18 species were found to infest the crop, out of which 3 were grassy *viz. Dactyloctenium aegyptium, Digitaria sanguinalis* and *Eragrotis tremula,* one was sedge (*Cyperus rotundus)* and 14 were broad-leaved weeds, *viz. Trianthema. portulacastrum, Digera arvensis, Molluga disticha, Tribulus terrestris, Cleome viscosa, Corchorus tridens, Corchorus olitrus Phyllanthus niruri, Portulaca oleracea, Cucumis callosus, Ipomea* spp.*, Physallis minima, Crotolaria* spp.*, Commelina benghalensis*. Among grassy weeds, *Dactyloctenium aegyptium* was most important weed with relative density of 48.9% and IVI value of 70%. This weed occurred at 85% of sites surveyed. *Cyperus rotundus* was major sedge with IVI value of 43.6% with relative frequency of 24.3% occurring at 48% sites surveyed. *Digera arvensis* and *Trianthema portulacastrum* were major broad-leaf weeds with relative density of 9.94 and 2.1%, relative frequency of 21.05 and 12.28% and IVI value of 31.0 and 14.4%, respectively. *Corchorus tridens* and *Tribulus terrestris* were other important weeds with IVI value of 6.36 and 6.17%, respectively. Climber *Ipomoea pestigridis* occurred at 2 sites only.

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Abundance, distribution and diversity of weeds in clusterbean

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Clusterbean is an important cash crop of south-western Haryana. Clusterbean is a poor competitor with weeds and suffers heavily due to weeds from the early growth stage due to favourable environment for weeds to thrive. Critical period of crop weed competition in clusterbean has been identified as 20-30 DAS and presence of weeds beyond this result in yield reductions by 47 to 92%. Crop type and soil properties have greatest influence on the occurrence of weed species. The type of irrigation, cropping pattern, weed control measures and environmental factors also have a significant influence on the intensity and infestation of weeds. So, knowledge of weed species associated with crops in a region is therefore pivotal and necessary to plan and execute a sound and economical weed management schedule depending upon various factors affecting weed distribution in different areas. Keeping this in view, a weed survey was conducted in three districts *viz.* Sirsa, Fatehabad and Bhiwani of Haryana during *Kharif* 2018.

In all 76 fields were surveyed during August 2018, as this period depicted most appropriate representation of majority of weed species. The road map of Haryana state was followed and routes were planned to establish sampling localities as equi-distantly as possible (about 10 kms) avoiding inhabited areas. Four observations on density of individual weeds were recorded per field at one spot by using quadrate of (0.5 x 0.5 m), 100 meters deep inside the fields as suggested by Raju (1977). Pooled average values of relative weed density, relative frequency of individual weeds and IVI were thus calculated as given below for each district separately.

The survey revealed that a total of 25 species were found to infest the crop, out of which 8 were grassy *viz. Dactyloctenium aegyptium, Digitaria sanguinalis, Brachiaria reptense, Leptochloa chinensis, Cynodon dactylon, Eragrotis pilosa, Elusine indica* and *Echinocloa colona*, two were sedges (*Cyperus* and Musa dadhi) and 15 were broad-leaved weeds *viz. T. portulacastrum, Digera arvensis, Molluga verticillatsa, Molluga disticha, Tribulus terrestris, Cleome viscosa, Corchorus tridens, Phyllanthus niruri, Portulaca oleracea, Cucumis callosus, Euphorbia* spp., *Ipomea* spp., *Physallis minima, Crotolaria medicaginea,* Gadtumba *(Citrullus lanatus)*. Among grassy weeds, *Dactyloctenium aegyptium* was most important weed with IVI value of 52.7%. *Cynodon dactylon* and *Brachiaria reptense* were other important grassy weeds with relative frequency of 4.78 and 1.71% and relative density of 2.89 and 1.1%, respectively. The IVI value for *Cynodon dactylon* and *Brachiaria reptense* was 7.67 and 2.71% respectively. *Digera arvensis* and *Corchorus tridens* were major broad-leaf weeds with relative density of 20.39 and 5.23%, relative frequency of 12.97 and 9.22% and IVI value of 33.36 and 14.50%, respectively. *Mollugo verticillata* and *Cleome viscose*, the weed of loamy sand soils showed their presence in Bhiwani district only. Among sedges, *Cyperus rotundus* is a major weed with relative frequency and relative density of 10.58 and 8.77%, respectively. Keeping the weeds in view, weed management practices can be followed for better growth and yield of crop.

Integrated weed management in soybean through front line demonstrations in farmers' fields

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The domestic requirement of oilseed had been manifold in a modern living standard which has been fulfilled through the imports that leads to imbalance in the Indian Economy. To fulfill the domestic demand and to boost the production and productivity, cluster frontline demonstrations (CFLDs) on soybean were conducted at farmers'fields through krishi Vigyan Kendra, Damoh. These demonstrations were conducted in two villages namely Jortala and Bamori during *Kharif* season of 2015-16 and 2016-17. The results of CFLDs showed a greater impact on farming community due to significant increase in crop yield than farmer practice The economics and benefit cost ratio of both farmers practice (FP) and recommended practice (RP) were workout. An average of ` 30990/ha was recorded net profit under RP while it was ` 18792/ha under FP. Benefit cost ratio was 2.10 under RP, while it was 1.87 under FP. By introducing the proven technology *i.e.* improved variety (J595-60), seed treatment, sowing in broad bed furrow, chemical weed management, recommended dose of fertilizer based on soil test results and integrated pest management by encouraging the farming community of the district through recommended technologies were followed in the CFLDs.

The front line demonstrations on weed management in soybean were conducted on farmers' field of Damoh district (M.P.) during *Kharif* season of 2015-16 and 2016-17 at two different locations under rainfed conditions. Prevailing farmer's practices were treated as control for comparison with recommended practice *i.e.* application of imazethapyr 35% + imazamox 35% WG at 70 g/ha at 15-20 days after sowing (DAS). The result of front line demonstrations showed a greater impact on farming community due to significant increase in crop yield than farmers practice. The economics and benefit cost ratio of both farmers practice (FP) and recommended practice (RP) were worked out. The weed intensity and weed biomass were found lower (51.5/m^2 and 45.7 g/m^2) than FP (275/m^2 and 251 g/m^2). An average of ` 26400/ha was recorded net profit under RP, while it was ` 14300/ha under FP. Benefit cost Ratio was 2.49 under RP, while it was 1.73 under FP. By introducing the proven technology *i.e.* chemical weed management, yield potential and net income from soybean in rainfed conditions can be enhanced to a greater extent with increase in the income level of the farming community of the district.

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Effect of crop establishment methods and sequential application of herbicides in late sown chickpea under rainfed low land ecology of Bihar

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Chickpea being slow in its early growth and short stature plant is poor competitor to weeds, especially during initial growth period suffers 17-85% yield loss depending upon the nature and intensity of weed flora and management practices (Singh *et al*. 2014). Weed management in chickpea at initial stage of crop growth is important since crop-weed competition is higher at this stage (Chouhan *et al*. 2018). Among all the agronomic practices sowing method assumes the great significance as it brings considerable change in plant environment with respect of spacing, light and availability of soil moisture and consequently influences the crop-weed competition and crop productivity. In the light of fragmental information available on the response of application of sequential application of herbicides under different sowing methods, a field experiment was conducted during winter season of 2013-14 to 2015-16 at KVK farm and five farmer's field. The soil of the entire experimental site was sandy clay loam in texture with neutral in reaction (pH-7.2). It was low in organic C (0.33%) and available nitrogen (168.9 kg/ha), medium in available phosphorus (26.6 kg/ha) and potassium (242.5 kg/ha) in soil surface. The experiment was laid out in split-plot design with two sowing methods, *viz*. reduced tillage (sowing was done by zero-till seed cum ferti drill after two tillage operation by cultivator), conventional tillage and five weed management practices, *viz*. weedy, weed free, pendimethalin 1.0 kg/ha pre-emergence, pendimethalin 750 g/ha pre-emergence *fb* imazethapyr (40 g/ha) at 25 DAS post-emergence and pendimethalin 750 g/ha pre-emergence *fb* quizalofop-ethyl 50 g/ha at 25 DAS post-emergence. In entire experimental plot eight weed species were identified and grouped in grasses, sedges and broad-leaved weeds. Composition of weed flora varies from sowing methods and weed management practices. Conventional tillage and weedy check plot recorded 10.2% *Phalaris minor*, 4.0% *Avena ludoviciana*, 4.0% *Cynodon dactylon*, 25.6% *Chenopodium album*, 15.0% *Rumex retroflexus*, 3.9% *Anagallis arvensis*, 24.7% *Vicia sativa* and 12.49% others.

Results revealed that chickpea sowing in reduced tillage performed better and produced higher number of pods per plant (72.64), seed yield (1.38 t/ha) and protein yield (290 kg/ha) over conventional tillage. Nitrogen (81.01 kg/ha), phosphorus (17.15 kg/ha) and potassium uptake (27.06 kg/ha) were recorded highest under reduced tillage over conventional tillage. In weed management treatment, sequential application of pendimethalin at 0.75 kg/ha pre-emergence (pre-em) followed by imazethapyr at 40 g/ha post-emergence improved the crop growth and produced higher seed yield (1.52 t/ha) and protein yield (316 kg/ha). Total weed density and weed dry weight were recorded minimum under reduced tillage at both 30 and 60 days after sowing. Application of pendimethalin at 0.75 kg/ha pre-em followed by imazethapyr at 40 g/ha post-em reduced the total weed density and weed dry weight over other treatments and recorded minimum. Among weed management practices sequential application of pendimethalin 0.75 kg/ha *fb* imazethapyr 40 g/ha significantly increased the uptake of nutrients (N, P and K) by crop over other treatments. Weed control efficiency was higher with conventional tillage (70.0%) and closely followed by reduced tillage (70.8%). Pendimethalin at 0.75 kg/ha pre-em *fb* imazethapyr at 40 g/ha recorded highest weed control efficiency (92.9%) followed by pendimethalin 0.75 kg/ha *fb* quizalofop-ethyl 50 g/ha (85.4%) and pendimethalin 1.0 kg/ha (73.8%).

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Integrated weed management in soybean

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A field experiment was conducted during *Kharif* season of 2010, 2011 and 2012 at Agricultural Research Station, Karad, Maharashtra to identify the suitable integrated weed management method in soybean. The experiment was laid out in randomized block design with ten treatments replicated thrice. Experimental treatments comprised of ten treatments *viz.* Weedy check, weed free check, hoeing at 15 days after seeding (DAS) and 30 DAS, hoeing at 15 DAS and hand weeding (HW) at 30 DAS, imazethapyr (Pursuit) 10% EC 0.075 kg/ha as post-emergence (POE) at 15 DAS, imazethapyr 10% EC 0.075 kg/ha as POE at 15 DAS and HW at 30 DAS, pendimethalin 1.0 kg/ha as pre-emergence, pendimethalin 1.0 kg/ha as pre-emergence and HW at 30 DAS, quizalofop- ethyl (Turga super) 5% EC 0.05 kg/ha + chlorimuron-ethyl (Cloben) 25% WP 0.009 kg./ha as post-emergence at 15 DAS and quizalofop- ethyl (Turga super) 5% EC 0.05 kg/ha + chlorimuron-ethyl (Cloben) 25% WP 0.009 kg/ha as post-emergence at 15 DAS + HW at 30 DAS. The experimental plot size was 6.0 x 4.2 m^2. The soybean was sown by dibbling at 30 x 10 cm spacing during *Kharif* 2010-2012. The soil of the experimental field was medium deep, with low in available nitrogen (260 kg/ha), high in available prosperous (45.2 kg/ha) and rich in available potash (350 kg/ha). The dominant weeds occurred in the experimental field were *Cynodon dactylon, Cyprus rotundus, Celosia argenta, Portulaca oleracea, Eclipta alba, Echinochlola colona, Alternenthra* spp., *Eupherbia* spp. *etc.* for three years. From the pooled data it was revealed that the mean yield attributes and yield of soybean were significantly influenced by different treatments. The significantly highest plant height (75 cm), number of pods per plant (29), grain yield (3.73 t/ha) and straw yield (2.59 t/ha) were obtained in weed free treatment. It was at par with treatment quizalofop- ethyl 5% EC 0.05 kg/ha + chlorimuron-ethyl 25% WP 0.009 kg/ha as post-emergence at 15 DAS + hand weeding at 30 DAS having grain yield (3.42 t/ha) and straw yield (2.45 t/ha). The B: C ratio was also highest in weed free treatment (3.05) which was followed by treatment quizalofop- ethyl 5% EC 0.05 kg/ha + chlorimuron- ethyl 25% WP 0.009 kg/ha as post-emergence at 15 DAS + hand weeding at 30 DAS (2.90). The lowest weed dry matter, higher weed control efficiency and lower weed index were recorded with weed free treatment. The second best treatment was quizalofop-ethyl 5% EC 0.05 kg/ha + chlorimuron-ethyl 25% WP 0.009 kg/ha as post-emergence at 15 DAS + hand weeding at 30 DAS with weed dry matter (38.1 g/m^2), higher weed control efficiency (62%) and lower weed index (8.0). On the basis of this study it was concluded that in soybean integrated weed management by quizalofop-ethyl 5% EC 0.05 kg/ha + chlorimuron-ethyl 25% WP 0.009 kg/ha as post-emergence at 15 DAS + hand weeding at 30 DAS was best for effective and economic weed control.

Weed dymanics, yield and economics of soybean under crop geometry and weed management practices

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A field investigation on "Growth, yield and economics of soybean [*Glycine max.* (L.) Merrill.] influenced by crop geometry and weed management practices" was conducted at Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra) during *Kharif*, 2015. The soil was silty clay in texture, medium in nitrogen (204.12 kg/ha), phosphorous (18.01 kg/ha) and very high in potassium (548.02 kg/ha). The experiment was laid out in factorial randomized block design with three replications and two crop geometry as main treatment and five weed management practices as sub treatment. The gross and net plot sizes was 6.00 x 5.40 m and 5.60 x 4.50 m, respectively. The recommended fertilizer dose (50:75:00 kg/ha) of N and P_2O_5 was applied as basal dose through urea and single superphosphate at the time of sowing of soybean. The dominant dicot weed flora associated with soybean crop in the experimental plot were *Trianthema portulacastrum* L., *Parthenium hysterophorus* L., *Digera arvensis* Forsk., *Cynotis axillaries* L., *Amaranthus viridis* L., *Euphorbia hirta* L., *Panicum isachmi* L. and *Paspalum dilatatum* L., while monocots were like *Dinebra retroflexa* L. and *Cynodon dactylon* L. *etc.* The lowest weed count at all the stages of observation was observed in treatment combination of 30 x 10 cm spacing with weed free check and 45 x 5 cm spacing with weed free check treatment combinations over the rest of the treatment combinations. The yield attributing characters and yield were significantly superior at 45 x 5 cm spacing. The weed management practices recorded significantly higher grain and straw yield in weed free check treatment than other treatments. The treatment combination of 45 x 5 cm spacing with weed free check recorded significantly higher growth attributes and yield over the rest of treatment combinations. Among the weed management combination of crop spacing at 45 x 5 cm with pendimethalin 38.7% CS PE 0.750 kg/ha recorded significantly the highest (92.95%) weed control efficiency. Significantly the lowest weed index value was noticed in the treatment combination of 45 x 5 cm with pendimethalin 38.7% CS PE 0.750 kg/ha indicating minimum percent reduction in seed yield in comparison to weed free check treatment. The herbicidal treatment combination of 45 x 5 cm with pendimethalin 38.7% CS PE 0.750 kg/ha *fb* one hand weeding at 30 DAS and 45 x 5 cm with pendimethalin 38.7% CS PE 0.750 kg/ha *fb* tank mix imazethapyr 10% SL + propaquizafop 10% EC (80+60 g/ha) at 25 DAS recorded maximum herbicide efficiency index values as compared to the remaining treatment combinations.

Response of summer blackgram to pre- and post-emergence herbicides under south Gujarat conditions

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A field experiment was conducted at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari during the summer season of 2014. The experiment was laid out in randomized block design with three replications and ten treatments, *viz*. weedy check, weedfree, pendimethalin at 1.0 kg/ha as pre-emergence (PE) + interculture (IC) at 30 DAS, pendimethalin at 1.0 kg/ha as PE + hand weeding at 30 DAS, pendimethalin at 1.0 kg/ha as PE + imazethapyr at 0.1 kg/ha at 30 DAS *i.e*. post-emergence (PoE), pendimethalin at 1.0 kg/ha as PE + quizalofop-p-ethyl at 0.05 kg/ha at 30 DAS (PoE), oxyfluorfen at 0.18 kg/ha PE + IC at 30 DAS, oxyfluorfen at 0.18 kg/ha PE + hand weeding at 30 DAS, oxyfluorfen at 0.18 kg/ha PE + imazethapyr at 0.1 kg/ha at 30 DAS (PoE) and oxyfluorn at 0.18 kg/ha PE + quizalofop- p- ethyl at 0.05 kg/ha at 30 DAS (PoE). Blackgram variety '*T-9*' was used in the experiment. The soil of experimental plot was clayey in texture with low in available N, medium P and fairly rich K. Herbicides were not found phytotoxic to the blackgram crop as reflected in initial and final plant stand of the crop. Significantly higher values of plant height (12.48 cm, 26.82 cm and 28.22 cm at 30, 60 DAS and at harvest, respectively), higher number of branches per plant, number of pods per plant, test weight, grain yield per plant, grain and stover yield were recorded under weed free treatment over rest of the treatments. Significantly the lowest values of growth and yield attributing parameters were registered under weedy check. Weed free treatment recorded significantly higher grain yield of 1250 kg/ha and remained at par with pendimethalin at 1.0 kg/ha as PE + hand weeding at 30 DAS, oxyfluorfen at 0.18 kg/haPE + handweeding at 30 DAS and pendimethalin at 1.0 kg/ha as pre-emergence (PE) + interculture (IC) at 30 DAS treatments which produced grain yield of 1219, 1188 and 1109 kg/ha, respectively. These three treatments was also recorded significantly lower weed count of monocot, dicot and sedge as compared to other treatments at 30, 60 DAS and at harvest. Lower weed density under these treatments also reflected in lower dry weight of weeds, lower weed index and higher weed control efficiency. The weedy check registered the highest reduction in grain yield of blackgram to the tune of 55.76 per cent as compared to weed free treatment. Chemical analysis of crop and weeds indicated that the significantly higher N, P and K uptake by the crop was recorded under weed free than rest of the treatments. While lowest depletion of N, P and K by weeds was under weed free. Significantly highest depletion of N, P and K nutrients by weeds were noted under weedy check. The maximum net realization of ` 52533/ha with B:C ratio 4.43 was obtained with weed free treatment which was closely followed by pendimethalin at 1.0 kg/ha as PE + handweeding at 30 DAS, oxyfluorfen at 0.18 kg/ha PE + handweeding at 30 DAS and pendimethalin at 1.0 kg/ha as pre-emergence (PE) + interculture (IC) at 30 DAS treatments which recorded net realization of ` 50357/ha, ` 49112/ha, and ` 44957/ha, respectively. Based on the results of one year experimentation, it is concluded that higher grain yield and net return from summer blackgram cv. '*T-9*' can be accured through keeping crop weed free throughout crop season. The next alternatives either of treatment pendimethalin at 1.0 kg/ha as PE + hand weeding at 30 DAS, oxyfluorfen at 0.18 kg/ha PE + hand weeding at 30 DAS or pendimethalin at 1.0 kg/ha as pre-emergence (PE) + interculture (IC) at 30 DAS can be adopted where farm labours are scarce, costly and not available timely.

Weed management in soybean

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Soybean is one of the important oilseed crops of India. Among the various factors responsible for low productivity of soybean, weed infestation during early stages of growth is one of the major factors. The integrated approach of weed control may be more feasible and practicable. With these considerations in view, the present experiment was undertaken at Mahatma Phule Krishi Vidyapeeth, Rahuri during *Kharif*, 2013-14. The experiment was laid out in randomized block design with eight treatments replicated thrice with combination of pre- and post-emergence herbicides with hand weeding and hoeing. The data on weed count and dry weight of weed were analyzed using square root transformation. The unweeded control registered significantly higher weed density and weed biomass due to luxuriant growth of the weeds in absence of any weed control treatments. The post-emergence application of metribuzin at 525 g/ha + 1 HW at 30 DAS registered significantly lower weed density (14.3/m^2) than rest of the treatments, While, pre-emergence application of metribuzin at 525 g/ha *fb* imazethapyr + propaquizafop-ethyl as post-emergence at 80 + 60 g/ha at 20 DAS recorded significantly lower weed biomass (75.2 g/m^2) than all other treatments. It might be due to pre-emergence application of metribuzin which prevented emergence of monocot and grassy weeds by inhibiting root and shoot growth and remaining monocot weeds were controlled by hand weeding at 30 DAS. Among integrated weed control treatments, post-emergence application of metribuzin at 525 g/ha + 1 HW at 30 DAS being at par with pre-emergence application of metribuzin at 525 g/ha *fb* imazethapyr + propaquizafop-ethyl as post-emergence at 80 + 60 g/ha at 20 DAS and pre-emergence application pendimethalin at 677.25 g/ha + 1 HW at 30 DAS attained significantly higher weed control efficiency of 85.2% than rest of the treatments. Post-emergence application of metribuzin at 525 g/ha + 1 HW at 30 DAS showed statistically lower weed index (3.7%) as compared to other treatments. Post-emergence application of metribuzin at 525 g/ha + 1 HW at 30 DAS recorded significantly higher grain yield of 2.38 t/ha and straw yield of 2.56 t/ha than all other treatments. The increase in yield might be because of less weed competition due to significant reduction in weed population and weed biomass which might have enhanced NPK uptake by crop and ultimately yield. Thus, it could be concluded that post-emergence application of metribuzin at 525 g/ha + 1 HW at 30 DAS was found most effective for controlling weeds and for obtaining higher yield of soybean.

Effect of weed management practices on growth and yield of mungbean (*Vigna Radiata* L.)

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The field experiment was carried out during three consecutive *Kharif* seasons of 2014, 2015 and 2016 at Pulses Research Station, S. D. Agricultural University, Sardarkrushinagar, Gujarat, to study the effect of different weed management practice on growth and yield of mungbean. The soil of experimental site was loamy sand in texture with 7.7 pH, low in organic carbon (0.16%), medium in available nitrogen (275 kg/ha), medium/ high in available P_2O_5 (47.6 kg/ha) and low in available K_2O (213.4 kg/ha). The experiment with total nine treatments of cultural and chemical weed management practices were evaluated in randomized block design with three replications. *i.e.*, T_1: pendimethalin 1.0 kg/ha –pre-emergence (PE), T_2: pendimethalin 30 EC + imazethapyr 2 EC [ready mixture (Vallore 32)] 1.0 kg/ha-PE, T_3: T_1 + quizalofop-ethyl 50 g/ha at 15-20 DAS-post-emergence (POE), T_4: T_2 + quizalofop-ethyl 50 g/ha at 15-20 DAS- POE, T_5: T_1 + Imazathapyr 40 g/ha at 15-20 DAS - POE, T_6: T_1 + Manual weeding at 25-30 days after sowing (DAS), T_7: T_2 + manual weeding at 25-30 DAS, T_8: Two manual weeding at 20 and 35-40 DAS and T_9: weedy check. Significantly the higher seed yield of 694, 1388 and 886 kg/ha was recorded with treatment of two manual weeding at 20 and 35-40 DAS during the year 2015, 2016 and in pooled results, respectively. However T_8 remains at par with treatments T_7, T_3 and T_6 in pooled analysis. Maximum net returns of ` 32750 per hectare and B-C ratio of 1.94 was incurred in treatment T_8 (Two manual weeding at 20 and 35-40 DAS) followed by T_2 and T_7 with B- C ratio of 1.69 and 1.68 per hectare, respectively. Significantly the lowest dry weight of weed at 30 DAS was recorded in pendimethalin 1.0 kg/ha-PE *fb* manual weeding carried out at 25-30 DAS during all the years and pooled analysis except in 2015. Further treatment T_6 was at par with treatments; T_4, T_7 and T_8 during 2014, T_4, T_5, T_7 and T_8 in 2015, T_7 and T_8 in 2016 and T_7 on pooled basis, was observed with Pendimethalin 1.0 kg/ha-PE *fb* manual weeding carried out at 25-30 DAS recorded maximum weed control efficiency at 30 DAS with a value of 95.03, 100.00 and 96.69% in the year 2014, 2016 and in pooled data. In *Kharif* season field should be kept weed free by two hand weeding at 20 and 35 to 40 DAS for getting higher seed yield and net return. Under constraint of labours it is advisable to apply either pendimethalin 30 EC + imazethapyr 2 EC (ready mixture) 1.0 kg/ha as pre-emergence followed by manual weeding at 25-30 DAS or pendimethalin 1.0 kg/ha –PE + quizalofop-ethyl 50 g/ha at 15-20 DAS- POE.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Weeding efficiency, growth and yield of chickpea as influenced by pre- and post-emergence herbicides

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Chickpea (*Cicer arietinum* L.), an important grain legume of the world, grown in 44 countries across five continents. Chickpea, the major pulse crop of India cultivated during *rabi* season, accounting for about 40.5% (9.38 MT) of total pulses production (23.13 MT) from nearly 32.7% of area (9.38 Mha) under pulses (29.44 Mha). Until 2002-03, its production was stagnant at around 3-5 MT, which has increased to 9.38 million tonnes (MT) in the year 2016-17. Chickpea yield is mostly stagnated at around 600 to 800 kg/ha in the country. Currently, productivity of chickpea is 974 kg/ha. Madhya Pradesh is the major chickpea producing state (accounting for about 27.19 per cent of total chickpea production in India) followed by Maharashtra (16.3%), Rajasthan (13.7%) and Uttar Pradesh (9.4%). Generally, chickpea is the poor competitor of weeds particularly during initial stages of crop growth. Because, it grows very slow, at the same time weeds compete with crops by proliferation of their growth. It is very difficult to control weeds which emerge in flushes. Therefore, weeds cause tremendous loss in terms of yield. Moreover, heavy flushes of weeds at the later stages of growth and non-availability of post-emergence herbicides in chickpea again aggravate the occurrence and prevalence of weeds. With that background, an agronomic investigation on "Efficacy of pre and post-emergence herbicides on weed dynamics, growth and yield of chickpea (*Cicer arietinum* L.)" was carried out at Agricultural Research Station, Mandor, Jodhpur during *rabi* season of 2016-17. The experiment comprising of sixteen weed management treatments were conducted in a randomized block design and replicated thrice. Among that two doses of each herbicides *i.e.* pendimethalin (0.40 and 0.60 kg/ha), oxyfluorfen (100 and 200 g/ha), imazethapyr (40 and 60 g/ha) with their combinations as pre and post-emergence including weedy check and weed free taken for computing WCE and WI, respectively. The results revealed that highest plant population (3.30 lakh/ ha), plant height (54.01 cm), branches/plant (7.50), pods/plant (49.83), seeds/pod (2.02), 100-seed weight (16.57 g), seed yield (2 t/ha) and stalk yield (3.31 t/ha) were recorded under sequential application of pre and post-emergence herbicides *i.e.* pendimethalin at 0.60 kg/ha (PE) + imazethapyr at 60 g/ha at 20 DAS, but it was equally effective with treatment pre- and post-emergence application of pendimethalin at 0.60 kg/ha (PE) + imazethapyr at 40 g/ha at 20 DAS. This might be due to effective weed control which is calculated in terms of weed control efficiency (94.21%) that lowered the yield losses in terms of weed index (1.03). Although, weed free reduces weed density which ultimately produced higher growth and yield attributes that accelerated the maximum seed yield and showed significant superiority over rest of the weed management treatments, but it was statistically at par with aforesaid two chemical treatments.

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Efficacy of pre- and post-emergence herbicides on summer urdbean in sub-tropical belt of Jammu region under irrigated conditions

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An investigation entitled "Efficacy of pre- and post-emergence herbicides on summer urdbean in sub-tropical belt of Jammu region under irrigated conditions" was conducted during summer seasons of 2015 and 2016 at research farm of Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu. Thirteen weed management treatments *viz.* imazethapyr 70 g/ha as pre-and post-emergence, imazethapyr 80 g/ha as pre- and post-emergence, imazethapyr + imazamox (RM) 70 g/ha as pre- and post-emergence, imazethapyr + imazamox (RM) 80 g/ha as pre- and post-emergence, pendimethalin 1000 g/ha as pre-emergence, imazethapyr + pendimethalin (RM) 1000 g/ha as pre-emergence, 2 hoeings (15 and 30 DAS), weedy check and weed free were laid out in randomized block design and replicated thrice to evaluate the efficacy of different herbicidal treatments on plant height, total weed density, weed control efficiency, seed yield and economics of summer urdbean. All the herbicides were applied by using a Knapsack sprayer fitted with flat-fan nozzle with spray volume of 500 litres water/ha. All the weed management treatments had a significant influence on plant height, total weed density, weed control efficiency and seed yield of summer urdbean. Significantly highest plant height, highest weed control efficiency and lowest total weed density was recorded with treatment weed free at 30 DAS. Amongst the different herbicidal treatments, imazethapyr + pendimethalin (RM) 1000 g/ha as pre-emergence recorded the highest plant height (24.93 cm, 27.26 cm), lowest total weed density (6.32/m^2, 6.11/m^2) and highest weed control efficiency (71.75%, 71.78%), respectively. Highest seed yield (910 kg/ha, 883 kg/ha) was observed with treatment weed free. Amongst the different herbicidal treatments, imazethapyr + pendimethalin (RM) 1000 g/ha as pre-emergence recorded the highest seed yield to the tune of (786 kg/ha, 743 kg/ha) which was statistically at par with all the post-emergence herbicides applied at 3-4 leaf stage (imazethapyr + imazamox (RM) 80 g/ha, imazethapyr 80 g/ha, imazethapyr + imazamox (RM) 70 g/ha and imazethapyr 70 g/ha). Highest B: C ratio of 2.56 and 2.29 was recorded with imazethapyr + pendimethalin (RM) 1000 g/ha as pre-emergence which was closely followed by imazethapyr + imazamox (RM) 80 g/ha applied at 3-4 leaf stage in 2015 and 2016.

Estimates of weed, insect and disease pest management indices in pest induced losses of Rapeseed (*Brassica campestris* var yellow sarson) for sustainable oil productivity

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Sustainable system agriculture is the need for our nation's food and oil security. Oilseed is the 2nd largest agriculture commodity next to food grains, sharing about 14% of the gross cropped area & 10% of all agricultural product values and 5% of gross national product. Indian oilseeds hold a distinct position accounting 19 and 9% of world's area and production, respectively, besides engaging 20 million people in country's oilseed works. Rapeseed-mustard is most popular in West Bengal with an average productivity of 684 kg (2017-18) only. The losses in oilseed crops due to biotic stresses are about 19.9% of which various plant pathogens, insects and weed pests affect the crop. The present experiment was carried out to find out the production losses caused by the major three pests weed, insect and disease and to evaluate the correlation between pest management indices and yield factors in rapeseed.

Field experiment was conducted in humid sub-tropics of Instructional Farm, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal during *Rabi* season of 2015 having 22°56' N latitude, 88°32' E longitude and at an altitude of 9.75 m above the mean sea level. The experiment was laid out in paired controlled and uncontrolled plots for each of the weed, insect and disease pest studies replicated six times and analysed under two sample T-test with equal variance and comparison of means by Fisher's t test. The plot size was 3 x 5 m maintaining 2 m buffers. The insect pest incidence was attended by mosquito nets in the protected plots. The rapeseed variety Benoy (B 9) was sown during October end with spacing of 30 cm (R-R) x 10 cm (P-P) and using balanced nutrition with neem cake at the rate of 5 t/ha and RDF of N:P:K:: 80:40:40 kg/ha. The indices related to weed, weed pest management, insect pest management, percent disease, disease pest management, overall pest management and agronomic management were worked out along with correlation study.

The results indicated that in protected plots weed competition was below the ETL and 32% yield loss could be recovered. Weed Pest Management Index (WPMI) implied 47% more efficient control in protected plots; Insect Pest Management Index (IPMI) and Disease Pest Management Index (DPMI) values registered 25 and 13% lesser competition, respectively in protected plots. The average Pest Management Index (PMI) of protected plots implied 29% additional contribution of seed yield of rapeseed crop by minimizing the losses in unprotected plots through reducing the crop pest competition. IPMI and Agronomic Management Index (AMI) value were positive indicating higher efficacy of utilizing available resources by reducing pests' competition. The correlation study between the three major pests' weed (density and biomass), insect (density) and disease (PDI) and major growth and yield attributes besides the biological yields revealed that proper ecosafe management is required in critical infestation period of pests, *i.e.* for weed pest initial one month; for insect and disease pest above 40 DAS and this sustainable pest management may help to improve the rapeseed oil productivity.

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Efficacy of different post-emergence herbicides in chickpea

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Chickpea is the major *Rabi* pulse crop in Maharashtra usually grown on residual soil moisture after harvesting of *Kharif* crop. There are many limitations of hoeing and hand weeding for weed management in chickpea as it requires more labour and increased the cost of cultivation. Post-emergence herbicides may be preferred for better weed management across the crop growth period. Keeping in view the limitation of other weed control methods for weed management, the use of different post-emergence herbicides will be effective and economical for broad spectrum weed control in chickpea.

A field experiment entitled “Efficacy of different post-emergence herbicide in chickpea (*Cicer arietinum* L.)” was carried out at the farm of AICRP on Weed Management, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) during *Rabi* season of 2016-17. The investigation was carried out to study the relative efficacy of different post-emergence herbicides on weeds, growth and yield of chickpea. The experiment was laid out in randomized block design replicated thrice with eleven treatments comprised of different post-emergence herbicides with different doses *viz.* quizalofop-ethyl (50 and 75 g/ha), oxyflourfen (150 g/ha), imazethapyr (50 g/ha), imazethapyr 35% + imazomox 35% (40 and 60 g/ha), clodinafop-propargyl + Na-aciflurofen 16.5% (300 and 500 g/ha), propaquizafop (100 g/ha) which were compared with two hand weeding (30 and 50 DAS) and weedy check. The predominant weed flora observed in field were *Chenopodium album*, *Euphorbia geniculate*, *Tridax procumbens*, *Digera arvensis*, *Digetaria sanguinalis*, *Parthenium hysterophorus*, *Celosia argentea*, *Ipomea* carnea, *Argemone mexicana*, *Cynodon dactylon*, chimanchara *etc.* The results revealed that among the various treatments under study, cultural practice of two hand weeding at 30 and 50 DAS followed by application of oxyflurofen at 150 g/ha and imazethapyr 10% at 50 g/ha effectively controlled the weeds and significantly enhanced the growth contributing characters of chickpea *viz.*, plant height, number of branches and dry matter accumulation per plant. In herbicidal treatments, the maximum growth and yield attributes were recorded with post-emergence application of oxyflourfen at 150 g/ha which was comparable with imazethapyr 10% at 50 g/ha . Yield attributes *i.e.* number of pods/plant, number of seeds/pod, grain weight/plant and 100 seed weight were significantly higher in oxyflourfen at 150 g/ha PoE application at 30 DAS. Among the herbicides, post-emergence application of oxyflourfen at 150 g/ha registered highest seed yield (1.96 t/ha) which was increased by 42.8% over the weedy check and was at par with imazethapyr 10% at 50 g/ha. Post-emergence application of oxyflourfen at 150 g/ha was found most economical after cultural practice of two hand weeding with maximum values of gross monetary returns (` 88358/ha) net monetary returns (` 58884/ha) and B:C ratio (3.0). Hence, it is concluded that for getting higher monetary returns and B: C ratio post-emergence herbicide would be definitely economical in situation where more labour wages are high, labour availability is uncertain during peak period and where intercultural operations and hand weeding are not possible due to unfavourable weather and soil condition.

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Economical weed control in soybean

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A field experiment entitled "Integrated weed managementin soybean **(***Glycine max* (L.) Merrill) was conducted during *Kharif* season of 2013-14 at Research farm of Mahatma Phule Krishi Vidyapith, Rahuri, Maharashtra. The experiment was laid out in randomized block design with eight treatments replicated thrice with combination of pre- and post-emergence herbicide along with hand weeding and hand hoeing. The soil of experimental field was silty clay, low in available nitrogen, medium in available phosphorus and high in potassium and was alkaline in reaction (pH 7.66). A full dose of nitrogen, phosphorus and potassium was applied as a basal application. Soybean variety DS 228 (Phule Kalyani) was sown 80 kg seed/ha at the spacing of 45 x 15 cm. Treatments consisted of pendimethalin pre- 677.25 g/ha + 1 HW at 30 DAS, metribuzin post- 525 g/ha + 1 HW at 30 DAS, pendimethalin pre - 677.25 g/ha *fb* bentazone + fenoxaprop- p-ethyl post-1000 + 80 g/ha at 20 DAS, metribuzin pre- at 525 g/ha *fb* bentazone + fenoxaprop-p- ethyl post-1000 + 80 g/ha at 20 DAS, pendimethalin pre - 677.25 g/ha *fb* imazethapyr + propaquizafop-ethyl post- 80 + 60 g/ha at 20 DAS, metribuzin pre - 525 g/ha *fb* imazethapyr + propaquizafop- ethyl post- 80 + 60 g/ha at 20 DAS, 1 Hoeing at 15 DAS and 2 HW at 25 and 45 DAS (weed free) and un weeded control.

The result revealed that the integrated weed management significantly affected soybean growth attributing characters and grain yield. This might be due to better control of weed in different stages of crop, manual weeding, intercultural operation at critical stage of crop reduce crop weed competition and thereby providing better growth (plant height, branches/plant), yield attributing characters (no. of pod/plant, pod weight/ plant, no. of seed/plant, weight of seed/plant, test weight) and ultimately yield. However, the highest net monetary returns of ` 48,181/ha was obtained in metribuzin post 525 g/ha at 20 DAS + 1 HW at 30 DAS and the highest benefit: cost ratio of 2.24 was also observed in metribuzin post 525 g/ha at 20 DAS+ 1 HW at 30 DAS, which was followed by metribuzin pre 525 g/ha *fb* imazethapyr + propaquizafop- ethyl post 80 + 60 g/ha at 20 DAS (2.21) and one hoeing at 15 DAS and two hand weeding at 25 and 45 DAS (2.10). The B:C ratio was high for herbicide treatment due to low cost of treatment as compared to mechanical method.

Thus, the combination of herbicide and mechanical method was most effective for weed control in soybean. Hence, metribuzin post at 20 DAS at 525 g/ha + 1 HW at 30 DAS was found economical viable method of managing weeds in soybean.

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Weed flora dynamics and growth response of green gram to weed management practices

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A field experiment was conducted at College of Agriculture, RVSKVV, Gwalior, India during *Kharif* 2017 to study the growth response of green gram and to control diverse weed flora through different weed management practices in organic farming. The experiment was laid out in a randomized complete block design, replicated three times, and consisted of 10 treatments as white plastic mulch, black plastic mulch, straw mulching 5 DAS 5 t/ha, one hand weeding at 20 DAS + straw mulching at 25 DAS, two hand hoeing at 20 and 40 DAS, two hand weeding at 20 and 40 DAS, hand weeding at 20 DAS + hoeing at 40 DAS, recommended herbicide (imazathapyr 80g/ha) + one hand weeding at 40 DAS and weedy check. The soil contained 0.51% organic carbon with the pH of 7.8 and electrical conductivity 0.34 dS/m in the top 15 cm of soil. The initial N (234 kg/ha) content of soil was low, P (14 kg/ha) and K (240 kg/ha) content was medium with sandy clay loam in texture.

Green gram variety '*TJM-3*' was sown with seed rate 18 kg/ha in rows 40 cm apart on 16th July 2017 and harvested on 4th October 2017. Seeds were treated with NPK culture (35 ml/kg seed) for 30 minutes to control soil and seed born diseases. FYM at 10 t/ha and vermicompost 10 t/ha were applied at the time of field preparation. Neem cake at 250 kg/ha was applied in the soil to control termite. Different mulching materials were placed five days after sowing. Irrigation was applied at all the critical stages of crop growth during the experimentation. Imazathapyr 80g/ha as PE was applied at appropriate rate and suitable timings with the help of knapsack sprayer with flat-fan nozzle at spray volume of 600 litres water/ha. Observations on weed density and dry matter of weeds were recorded from 1.0 m^2 quadrate in each plot to determine species wise weed density and dry weight of weeds at 40 DAS.

The highest mortality of weeds, weed control efficiency of 94.1% and the maximum grain yield of 824 kg/ha with 104% increase in grain yield over weedy check were recorded with one hand weeding at 20 DAS conjointly with straw mulching at 25 DAS. Whereas, the highest B:C ratio of (2.52) was obtained with application of imazathapyr 80g/ha as PE followed by imazathapyr 80g/ha with one hand weeding at 40 DAS (2.08).

Influence of spacing and weed management on weed density in sunflower

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Sunflower ranks fourth next to soybean, palm oil and canola as an oil seed crop in the world. It is the important source of edible oil in several parts of the world as it has got high amount of poly unsaturated fatty acids (PUFA). Fourteen percent of the world's edible oil demands are met by sunflower. It is one of the fastest growing oilseed crop in India. One of the causes for low yield is the weed growth which compete with the crop for nutrients, water, sunlight and space. Sunflower being a wide spaced crop and slow growth during the early stage of the crop, provides enough room for weeds to establish and take advantage of slower initial growth of the crop. Experiment was conducted with the objective of reducing the weed density by altering the spacing to suit the weed management practices.

Field trial was conducted at Tamil Nadu Agricultural University, Coimbatore to study the response of various spacing and weed management practices on total weed density in sunflower at 60 DAS during *Kharif* 2016-17. Experiment was laid out in strip plot design with five horizontal factors as spacing and five vertical factors as weed management practices. Lesser density of total weeds was recorded with the treatment combination of the spacing 75 x 25 cm along with the hand weeding at 15 and 30 DAS, spacing 60 x 30 cm along with the hand weeding at 15 and 30 DAS and 75 x 25 cm along with pre-emergence pendimethalin at 1 kg/ha followed by power weeder weeding at 30 DAS compared to other treatment combinations. The spacing 90 x 20cm with weedy check recorded higher density of total weeds.

Wider row spacing might have enabled the weeds to utilize more sunlight, moisture and nutrients during the early stage of the crop. Among the spacings, 90 x 20 cm followed by spacing 90 x 15 cm recorded higher density of weeds. Lower density of weeds was with the spacing 75 x 25 cm and 60× 30 cm due to closer planting and quick coverage of canopy by sunflower crop as compared to wider row spacing. With regard to weed management practices, the least weed density was recorded with hand weeding twice at 15 and 30 DAS, pre-emergence application of herbicide pendimenthalin and hand weeding at 30 DAS and pre-emergence application of herbicide pendimenthalin and power weeder weeding at 30 DAS. The early and late emerging weeds were controlled by hand weeding at 15 and 30 DAS. Hand weeding resulted in better removal of underground root portions. The integrated weed management practices also performed equally effective as that of mechanical methods of weed control. Due to effective control of early emerging weeds by the pre-emergence herbicide application and late emerging weeds by mechanical methods either hand weeding or power weeder weeding. Significant interaction between spacing and weed management practices on weed density at 60 DAS of *Kharif* 2016-17. The spacing 75 x 25 cm or 60 x 30 cm combined with hand weeding twice registered lower weed density, due to optimum spacing and effective control of weeds by hand weeding.

Management of major insect pests and weeds of soybean through insecticide-herbicide combinations

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Soybean has already established as one of the substitute crop for major *Kharif* cash crop in Vidarbha. The improved production technology has increased the productivity of soybean in Vidarbha. As the area under soybean cultivation is increasing day by day and farmers is cultivated soybean on same piece of land lacking crop rotation and now facing a problem of weed as well as pest management. It is very difficult to control weeds and pest at a very initial stage of crop growth. In the month of June-July, due to heavy rainfall received, several weeds emerges and compete with the main crop. At the same time there is a heavy infestation of semi-looper and other pest are also found in some pockets of Vidarbha region. So, time management becomes a very important issue to control both weed and pest in rainy season.

The present investigation was undertaken, to manage weeds and pest of soybean crop at the same time and increase soybean production and to find out suitable combination of insecticide-herbicide.

The experiment was conducted during 2014-15 in randomized block design with three replications consisting of Twelve treatments, *viz.*- rynaxypyre 20 SC at 100 ml/ha, indoxacarb 14.5 SC at 300 ml/ha, quinalphos 25 EC at 1.5 L/ha, imazethapyr 10 SL at 1.0 L/ha, quizalofop-ethyl 5 EC at 1.0 L/ha and their insecticide-herbicide combinations. All the treatments were compared with untreated check.

At 30 DAS lowest weed count and dry matter accumulation was recorded in treatment quizalofop-ethyl 5 EC at 1.0 L/ha *i.e.* 15.67 and 19.67 weed count and 8.98 and 11.55 g/plant respectively but found at par with Rynaxypyre 20 SC at 100 ml/ha + quizalofop-ethyl 5 EC at 1.0 L/ha. More or less similar trend was observed at 45 DAS. At 60 DAS, significantly lowest weed count was observed in treatment imazethapyr 10 SL at 1.0 L/ha *i.e.* 32 and 26.41 total no. of weeds and dry matter per plant respectively. Whereas highest weed control efficiency at 30 and 45 DAS was found in treatment quizalofop-ethyl 5 EC at 1.0 L/ha *i.e.* 71.81 and 54.46%, respectively. At 60 DAS, it was recorded in treatment imazethapyr10 SL at 1.0 L/ha (62.04%).

Significantly highest soybean seed yield was observed in treatment rynaxypyre 20 SC at 100 ml/ha + imazethapyr 10 SL at 1.0 L/ha *i.e.* 1.47 t/ha but was found at par with other treatments. More or less similar trend was observed in respect of branches and pods per plant. Test weight was found to be non- significant.

Highest COC, NMR an B:C ratio was recorded in treatment Rynaxypyre 20 SC at 100 ml/ha + Imazethapyr10 SL at 1.0 L/ha *i.e.* ` 32393, ` 16055 per ha and 1.50, respectively.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Effect of weed management practices on weed dynamics and yield of clusterbean varieties under different crop geometries

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Clusterbean commonly known as Guar, is a drought and high temperature tolerant deep rooted summer annual legume of high social and economic significance. The qualities of the crop like high adaptation towards erratic rainfall, multiple industrial uses and its importance in cropping system have made the guar one of the most significant crops for farmers in arid areas in India.

The experiment was conducted during *Kharif* seasons 2015 and 2016 at the Research Farm, RVSKVV, College of Agriculture; Gwalior (M.P.). The treatments consisted of 24 combinations comprising two varieties (*HG 563* and *HG 2-20*) and two crop geometries (30 x 10 cm and 45 x 6.5 cm) as main-plots and six weed management practices (cycloxidim 20% SC at 100 g/ha, imazethapyr 10% EC at 40 g/ha, imazethapyr 10% EC at 75 g/ha, imazethapyr 35% WG + Imazamox 35% WG (Pre-mix) at 40 g/ha, weed free and weedy) as sub-plots with three replications in split plot design with keeping a seed rate of 20 kg/ha. The periodical observations were recorded on weed parameters, *viz.* population/m^2, dry weight, weed growth rate, weed control efficiency, and nutrient uptake and crop parameters, *viz.* seed yield, nutrient uptake, and nutrient balance as per prescribed procedures.

The 30 x 10 cm crop geometry observed significantly better under all weed and crop parameters in respect to 45 x 6.5 cm. The whole findings revealed that the weed free treatment was significantly effective in case of all weed parameters and crop parameters. Among herbicidal treatments; imazethapyr 35% WG + Imazamox 35% WG (Pre-mix) at 40 g/ha followed by imazethapyr 10% EC at 75 g/ha achieved statistically at par and significantly impressive results over rest of the treatments.

The all weed and crop parameters were found significantly expressive under interaction of variety *HG 2-20* with 30 x 10 cm crop geometry over rest of the interactions. The interaction of variety *HG 2-20* with weed free situation recorded significantly superior values of all weed parameters and crop parameters. Among interaction of herbicidal treatments with varieties; variety HG 563 with imazethapyr 35% WG + imazamox 35% WG (Pre-mix) at 40 g/ha was observed significantly superior over rest of the interactions.

The interaction of 30 x 10 cm crop geometry and weed free situation registered significantly profitable under all weed and crop parameters. Among interaction of herbicidal treatments with crop geometries; 30 x 10 cm crop geometry with imazethapyr 35% WG + imazamox 35% WG (Pre-mix) at 40 g/ha was significantly expressive over rest of the interactions.

Among interaction of herbicidal treatments with varieties and crop geometries; imazethapyr 35% WG + imazamox 35% WG (Pre-mix) at 40 g/ha combined with *HG 2-20* variety and 30 x 10 cm crop geometry earned significantly effective value over other interactions.

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Variable rate herbicide application system for weed eradication in row crops

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Herbicides are chemicals, which are designed to kill or control the unwanted plants (weeds) in cropping or non-cropping situations. Precise application of herbicide is the key requirement for environment friendly and economical crop production. In this regard a tractor rear mounted six-row contact-type herbicide applicator was developed at IITK. The system works on the principle of detecting green index of weed plants. The system estimates the weed density between crop rows through machine vision in real time and proportionally applies the amount of chemical herbicide. The weed density was estimated as the ratio of number of green pixels to the total number of pixels within an image frame. The greenness of a pixel was identified by setting up threshold values in a hue, saturation and value model of color space to also account for variability in natural illumination. The other electronic components include single board micro processor, processing computer with custom developed machine vision algorithm and graphic user interface, relay switches, solenoid valves, hall effect flow sensor and proximity switch. The graphic user interface enables user for parametric adjustments of the threshold reflectance values for weed detection as per the change in natural illumination conditions. The application unit comprises of solenoid valves, drop down pipelines and sponge covered rollers that move over weeds for herbicide application. An inductive type position sensor was also installed for identifying the correct location of herbicide application. The applicator intends for parallel herbicide application in six rows and thus six individual cameras and application units were fabricated and assembled. The deflectors were also placed for restricting the entrance of main crop plants into camera's field of view. It ensures the accurate estimation of weed density and avoids the crop damage. The change in flow rate of herbicide through solenoid valves, proportional to weed density variation was recorded using a Hall-effect flow sensor. The concept of the pulse width modulation was applied for variable rate application of herbicide where its required amount was released for a calibrated duty cycle (time). Since the standard traverse speed for weeding operations is recommended as 2.1 km/h, the frame rate and processing algorithm were designed accordingly. The cameras were positioned at a height to cover a FOV of 60 x 30 cm per frame.

The performance of the developed weed eradicator system was evaluated and compared for contact-type and spray-type applications for two selected groundnut and maize crops. The appropriate concentration level of paraquat dichloride was maintained at 1:10 within water for field application. During the field application, damaged plants along with weeding efficiency, application rate and herbicide savings were recorded. This variable-rate weed eradicator was able to significantly save the herbicide amount by about 79.50% over conventional method of constant spraying, while maintaining a weeding efficiency of 90.26%. Further, this technology can potentially avoid chemical losses through drift and soil percolation, thereby leading to a smooth and eco-friendly weed eradication.

Effect of integrated weed management on yield and economics of soybean in Satpura plateau of Madhya Pradesh

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The field experiment was conducted at Krishi Vigyan Kendra, Chhindwara, during the *Kharif* season of 2016 and 2017 with a view to study "Effect of integrated weed wanagement on yield and economics of soybean in Satpura plateau region of Madhya Pradesh". The soil was sandy loam in texture, neutral in reaction having medium fertility level of available NPK. The treatments included *viz.* weedy check, one hand weeding (HW) 20 DAS, two HW 20 and 40 DAS, pre-sowing incorporation of fluchloralin 1.0 and 1.5 kg/ha, pendimethalin 1.0 kg/ha, imazethapyr 1.0 kg/ha**,** quizalofop ethyl 1.0 kg/ha, pendimethalin 1.0 kg/ha + one hand weeding 40 DAS and using two time stale seed bed technique (weed free). Soybean JS 20-69 was sown on 20 June in both the years following ridge and furrow system. Ten treatments were replicated thrice in a CRBD. The results indicated that mean maximum number of pods/plant (69), number of pods/m^2 (1193), number of seeds/pod (2.65) and test weight (12 g/100 grains) were recorded in weed free treatment. The same treatment also resulted in mean highest biological yield (7.0 t/ha), harvest index (36%), seed yield (2.58 t/ha) straw yield (4.46 t/ha) with net profit (` 56425/ha) and B:C ratio (2.54). This was followed by treatment of pendimethalin 1.0 kg/ha + one hand weeding 40 DAS resulting in better effect on different parameters, yield and economics. Weedy check (control) plot showed the lowest effect on different parameters, yield and economics of soybean crop. On the basis of findings it could be suggested that twice stale seed bed preparation may be followed for higher yield and economic returns in soybean crop.

Bio-efficacy of pre-mix and tank-mix herbicides on weed control efficiency and yield of groundnut

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A field experiment was conducted to study the bio-efficacy of herbicide mixtures on weed control and yield of groundnut (*Arachis hypogaea* L.) during *Rabi*, 2016 at the wetland farm of S.V. Agricultural College, Tirupati. The experimental soil was sandy loam in texture, slightly alkaline in reaction (pH 7.7), low in organic carbon (0.38 per cent) and available nitrogen (158.0 kg/ha), medium in available phosphorus (23.4 kg/ha) and available potassium (211.3 kg/ha). The experiment was laid out in a randomized block design having three replications with ten treatments. The predominant weed species associated with groundnut were *Cyperus rotundus* (52.0%), *Digitaria sanguinalis* (10.0%), *Commelina benghalensis* (8.0%), *Phyllanthus niruri* (6.0%), *Cleome viscosa* (5.0%), *Boerhavia diffusa* (5.0%) and *Dactyloctenium aegyptium* (5.0%). The test variety of groundnut '*Dharani'* was used in the study by adopting spacing of 22.5 x 10 cm. The results of the experiment indicated that hand weeding twice at 20 and 40 DAS recorded highest weed control efficiency, hundred pod weight, and pod yield in groundnut, which was at par with pre-emergence application of pendimethalin at 1000 g/ha *fb* one hand weeding at 20 DAS and post-emergence application of imazethapyr at 37.5 g/ha + quizalofop-ethyl at 25 g/ha. In conclusion, the study reaveled that the highest weed control efficiency and yield attributes was recorded with hand weeding twice at 20 and 40 DAS, which was on par with pre-emergence application of pendimethalin *fb* one hand weeding at 20 DAS, or post-emergence application of imazethapyr + quizalofop-ethyl.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Efficacy of herbicides on weed control in Summer groundnut

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A field experiment was conducted in RBD with three replicates having six treatments of pre- and post-emergence herbicides application in *Summer* Groundnut to find out appropriate pre- and post-emergence herbicides for maximum weeds control and yield enhancement under *Summer* groundnut. The experiment was conducted during *Summer* 2017 at Oilseeds Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (MS) India. The gross and net plot size were 3.60 x 3.0 m^2 and 3.0 x 2.80 m^2, respectively. The crop variety TAG 24 was sown at 30 x 10 cm. The recommended dose of fertilizer 25:50:0 NPK kg/ha was used. The 25 kg/ha nitrogen and 50 kg/ha P_2O_5 were applied as basal dose was given at sowing. Urea (46%) and SSP (16% P_2O_5) used respectively. The results revealed the lowest weed index (17.27%) was observed under pendimethalin 30% E.C. 1.5 kg/ha *fb* imazethapyr 10% S.L. 75 g/ha 20-30 DAS than pendimethalin 30% E.C. 1.5 kg/ha *fb* quizalofop-p-ethyl 5% E.C. 50 g/ha 20-30 DAS (19.28%). The minimum weed dry weight was also recorded in these treatments, which was significantly lower than all other treatments. Maximum weed control efficiency (84.32%) was recorded in pendimethalin 30% E.C. 1.5 kg/ha *fb* imazethapyr 10% S.L. 75 g/ha 20-30 DAS and minimum weed control efficiency recorded under pendimethalin 30% E.C. 1.5 kg/ha *fb* one hand weeding at 25 DAS (71.78%). This clearly indicated that weeds were controlled effectively under pendimethalin 30% E.C. 1.5 kg/ha *fb* imazethapyr 10% S.L. 75 g/ha 20-30 DAS. Mean yield of dry pods per hectare as affected by various treatments showed that weed free treatment gave highest dry pods yield (2.08 t/ha) followed by two hand weeding 20 and 40 DAS (1.81 t/ha), pendimethalin 30% E.C. 1.5 kg/ha *fb* one hand weeding at 25 DAS (1.77 t/ha), pendimethalin 30% E.C. 1.5 kg/ha *fb* imazethapyr 10% S.L. 75 g/ha 20-30 DAS (1.72 t/ha), pendimethalin 30% E.C. 1.5 kg/ha *fb* quizalofop-p-ethyl 5% E.C. 50 g/ha 20-30 DAS (1.68 t/ha) which were statistically at par with each other. The lowest yield was recorded in weedy check (991 kg/ha). More or less similar trend was noticed with growth and yield parameters. Among the treatments in pendimethalin 30% E.C. 1.5 kg/ha *fb* imazethapyr 10% S.L. 75 g/ha at 20-30 DAS recorded maximum gross monetary return (` 79839/ha) and net monetary return (` 51737/ha) which were at par with pendimethalin 30% E.C. 1.5 kg/ha *fb* quizalofop-p-ethyl 5% E.C. 50 g/ha 20-30 DAS but significantly higher as compared to other treatments. Herbicidal treatments resulted in considerably lower cost of cultivation compared with hand weeding. The B:C ratio was found maximum with pendimethalin 30% E.C. 1.5 kg/ha *fb* imazethapyr 10% S.L. 75 g/ha 20-30 DAS (2.84) than other treatments. Hence for getting maximum economic return from summer groundnut application of pre- and post-emergence herbicide spraying of pendimethalin 30% E.C. 1.5 kg/ha *fb* imazethapyr 10% S.L. 75 g/ha or pendimethalin 30% E.C. 1.5 kg/ha *fb* quizalofop-p-ethyl 5% E.C. 50 g/ha in 500 litre water at 25-30 DAS (2-5 leaf stage weeds) for effective controlling weeds, higher dry pods yield in *Summer* groundnut.

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Integrated management of nutrient and weed in yellow sarson [*Brassica rapa* L. var. trilocularis (Roxb.) Kitam] under rainfed condition

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An experiment entitled "Integrated management of nutrient and weed in yellow sarson (*Brassica rapa* L. var. *trilocularis* (Roxb.) Kitam) under rainfed condition" was conducted at Instructional-cum-Research Farm, Assam Agricultural University, Jorhat during *rabi* seasons of 2016-17 and 2017-18 to find out the effect of integrated weed management (IWM) on growth and yield of yellow sarson and a suitable integrated nutrient management (INM) practice for yellow sarson. The experiment was laid out in factorial randomized block design with three replications. The treatments consisted of five INM practices *viz.*, control (N_0), RDF (60-30-30 kg/ha N, P_2O_5, K_2O, N_1), 25% RDF + 75% of N through vermicompost (N_2), 50% RDF + 50% of N through vermicompost (N_3) and 75% RDF + 25% of N through vermicompost (N_4), and, three IWM practices *viz.*, weedy check (W_0), pendimethalin 0.75 kg/ha pre-em + MW 20 DAS (W_1) and pendimethalin 1.0 kg/ha pre-em + MW 20 DAS (W_2). The soil of the experimental site was sandy loam in texture, acidic in reaction (pH: 5.6 and 5.5), medium in organic carbon (0.58% and 0.54%), available N (259.86 kg/ha and 255.75 kg/ha) and available K_2O (160.82 kg/ha and 156.49 kg/ha) and low in available P_2O_5 (20.87 kg/ha and 20.00 kg/ha) in the years 2016-17 and 2017-18, respectively. The weed flora of the experimental field were *Paspalum conjugatum* L., *Axonopus compressus* (Sw.) P. Beauv., *Cynodon dactylon* (L) Pers., *Panicum repens* L., and *Eleusine indica* (L) Gaertn., among the grasses; *Cyperus esculentus* L. among the sedge; and *Alternanthera philoxeroides* Griseb., *Soliva anthemifolia*, *Ageratum houstonianum* Mill., *Oxalis corniculata* L., *Melochia corchorifolia* L., *Chenopodium album* L., *Commelina benghalensis* L., *Mimosa pudica* L. and *Polygonum plebeium* R. Br.

The density and dry weight of weeds during both the years were found to be significantly lesser with N_4 compared to rest of the treatments. As a result, the content and uptake of N, P and K by weeds were found to be significantly lesser with N_4. Moreover, the growth parameters (barring N_3 which was at par with N_4) and yield attributing characters were significantly improved due to N_4. The highest seed yield (969 and 949 kg/ha during 2016-17 and 2017-18, respectively) and stover yield (2921 and 2846 kg/ha during 2016-17 and 2017-18, respectively) of yellow sarson were recorded with N_4. The oil content, oil yield, N, P and K content and uptake also increased with N_4.

Pendimethalin 1.0 kg/ha pre-em + MW 20 DAS (W_2) was found to result in significantly lesser density and dry weight of weeds with lower NPK content and uptake in weeds. The growth and yield attributing characters of yellow sarson were improved with W_2 which also recorded the highest seed yield (964 and 943 kg/ha during 2016-17 and 2017-18, respectively) and stover yield (2900 and 2830 kg/ha during 2016-17 and 2017-18, respectively). The oil content, oil yield, N, P and K content and uptake were significantly higher with W_2. The INM interacted significantly with IWM in respect of seed and stover yields of yellow sarson and N_4W_2 was found to be superior with 1210 and 1190 kg/ha seed yield and 3673 and 3570 kg/ha stover yield during 2016-17 and 2017-18, respectively.

In respect of economics, N_4W_2 resulted in the highest gross return (` 62336/ha and ` 61285/ha during 2016-17 and 2017-18, respectively), net return (` 39378/ha and ` 38327/ha during 2016-17 and 2017-18, respectively) and benefit:cost ratio (2.71 and 2.66 during 2016-17 and 2017-18, respectively).

Efficacy of pre- and post-emergence herbicides for weed management in chickpea

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A field experiment entitled "Efficacy of pre- and post-emergence herbicides for weed management in chickpea (*Cicer arietinum* L.)" was carried out during *Rabi* season of 2016 at the Instructional Farm, Department of Agronomy, College of Agriculture, JAU, Junagadh. The experiment comprising 12 treatments was laid out in randomized block design with three replications. The results revealed that next to the weed free treatment, significantly higher values of growth parameters, *viz*. plant height, number of branches/plant and leaf SPAD value, yield attributes and yield, *viz*. number of pods/plant along with seed yield and stover yield, quality parameters *viz*., protein content and N, P and K content and uptake by seed and stover were recorded with application of oxyfluorfen 0.18 kg/ha as pre-emergence *fb* pre-mix (imazamox + imazethapyr) 0.03 kg/ha post-emergence at 40 DAS and two HW at 20 and 40 DAS. Besides, weed free condition, oxyfluorfen 0.18 kg/ha as pre-emergence *fb* pre-mix (imazamox + imazethapyr) 0.03 kg/ha post-emergence at 40 DAS and two HW at 20 and 40 DAS were found more effective in reducing the weed population up to harvest and resulted in less dry weight of weeds, lower weed index and higher weed control efficiency and herbicidal efficiency index. The highest net return of ` 72040/ha was realized with oxyfluorfen 0.18 kg/ha as PE *fb* pre-mix (imazamox + imazethapyr) 0.03 kg/ha PoE at 40 DAS followed by the treatments weed free and two HW at 20 and 40 DAS. However, the highest BCR of 3.54 was obtained with the treatment oxyfluorfen 0.18 kg/ha as PE *fb* pre-mix (imazamox + imazethapyr) 0.03 kg/ha PoE at 40 DAS.

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Efficacy of herbicides on weed control in *Rabi* groundnut under east and south eastern coastal plains of Odisha

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Groundnut (*Arachis hypogaea* L.) is one of the major edible oilseed crop containing 26% protein and 45% oil. This crop is highly susceptible to weed infestation because of its slow growth in the initial stages up to 40 days, short plant height and underground pod bearing habit. Weeds may cause substantial yield losses (15-75%) which are more in rainfed Spanish bunch type. Besides competing for nutrients, soil moisture, sunlight; weeds inhibit pegging, pod development in groundnut and interfere with harvest. Hence, the present study was planned to study the effect of various herbicide alone and in combination to test their herbicidal efficiency *vis-a-vis* improvement in growth and yield of groundnut under Eastern and South Eastern Coastal plain of Odisha. The experimental site was situated at $20^{0}16'$ N latitude $85^{0}47'$ E longitude with a MSL of 25.9 m. The experiment was laid out in randomized block design with 3 replications consisting of 6 treatments like weed free check, two hand weeding (at 20 and 40 DAS), pendimethalin 30% E.C. at 1 kg/ha + one hand weeding at 25 DAS, pendimethalin 30% E.C. at 1 kg/ha + quizalofop-p-ethyl 5% E.C. at 50 g/ha 20-30 DAS (at 2-5 leaf stage weeds), pendimethalin 30% E.C. at 1 kg/ha + imazethapyr 10% S.L. at 75 g/ha at 20-30 DAS (at 2-5 leaf stage weeds) and one HW(25 DAS)-farmer's practice along with one control (check) during *Rabi* 2016-17. The textural class of the soil was sandy Loam with pH 5.2, organic carbon 0.38%, available N 232 kg/ha, P_2O_5 17 kg/ha and K_2O 82 kg/ha. Groundnut variety "Devi" was sown on 17.11.2016 at a spacing of 30 x 10 cm. The different herbicides were imposed as pert the treatment by using a flat fan nozzle with the help of a knapsack sprayer of 500 litre water per ha. All standard agronomic procedures were followed during the crop growing period. The different weeds observed in the experimental site were *Digitaria ciliaris, Digitaria sanguinalis, Eleusine indica* and *Dactyloctenium aegyptium* under grass category, *Cyperus rotundus* under sedge category and *Borreria hispida, Cleome viscosa, Eclipta alba, Celosia argentea, Phyllanthus niruri, Tephrosia purpurea, Ludwigia parviflora* and *Physalis minima* among broad-leaf weeds. Among the weed management practices, pendimethalin 30% E.C. at 1 kg/ha applied at pre-emergence coupled with one hand weeding at 25 DAS was found promising in reducing the weed density, weed dry weight and in enhancing the yield attributing characters and pod yield (1.9 t/ha) of groundnut in addition to benefiting monetary returns with net return of ` 40,409/ha and B:C ratio of 1.78. This combination was comparable to that of hand weeding twice at 20 and 40 DAS with pod yield (1.8 t/ha), net return (` 39324/ha) and B:C ratio of 1.71.

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Weeds and pigeonpea productivity under integrated crop management practices

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In India, pigeonpea occupies 5.4 million ha area with annual production of 4.8 million tonnes with an average yield of 885 kg/ha. The productivity of pigeonpea is very low due to poor adoption of improved technology, early seedling mortality due to water stagnation, severe weed infestation due to wider spacing and pest infestation as well. Weed management is crucial in pigeonpea as weeds have potential to cause yield loss up to 75 to 80% in pigeonpea if allowed to grow till harvest. Thus, a field experiment was initiated in the year 2015 in pigeonpea-wheat cropping system with weed studies undertaken after two years of experimentation in pigeonpea during *Kharif* 2017 at the Experimental Farm of IARI, New Delhi, India. The experiment was laid-out in RBD with 3 replications and 9 integrated crop management modules (ICM), *viz*. Conventional tillage (CT) + flat-beds (FB) + 100% RDF + pendimethalin as pre-emergence (PE) at 1 kg/ha followed by (*fb*) imazethapyr at 75 g/ha as post-emergence (POE) at 25 DAS + 1 hand-weeding and its mulching at 40 DAS (1 HWM) + 3 irrigations (Irr); CT–FB + 75% RDF + AM fungi (AMF) + NPK-biofertilizers (NPK-bf) + pendi-PE *fb* imaze-POE + 1 HWM + 3 irr; CT + raised-beds (RB) + 100% RDF + pendi-PE *fb* imaze-POE + 1 HWM + 2 irr; CT–RB + 75% RDF + AMF + NPK-bf + pendi-PE *fb* imaze-POE + 1 HWM + 2 irr; Zero-tillage(ZT) + FB + wheat crop residues retention (CRR) at 3 t/ha + 100% RDF + glyphosate pre-planting (PP) at 1 kg/ha 15 days prior to sowing *fb* pendi-PE *fb* imaz-POE + 1 HWM + 2 irr; ZT–FB + CRR at 3 t/ha + 75% RDF + AMF + NPK-bf + glypho-PP *fb* pendi-PE *fb* imaze-POE + 1 HWM + 2 irr; ZT + permanent raised-beds(PRB) + CRR at 3 t/ha + 100% RDF + glypho-PP *fb* pendi-PE *fb* imaze-POE + 1 HWM + 2 irr; ZT–PRB + CRR at 3 t/ha + 75% RDF + AM fungi + NPK-bf + glypho-PP *fb* pendi-PE *fb* imaze-POE + 1 HWM + 2 irr; CT–FB + CRR at 3 t/ha + FYM at 5 t/ha + AM fungi + NPK-bf + 2 HWM at 20 and 40 DAS + 2 irr. The need-based organic IDM/IPM was followed. After two cropping cycles of pigeonpea-wheat system, the predominant weed flora found in pigeonpea were *Digitaria sanguinalis*, *Cynodon dactylon*, *Eragrostis tenella* and *Dactyloctenium aegyptium* among grassy weeds; *Trianthema portulacastrum*, *Digera arvensis*, *Euphorbia hirta* and *Commelina benghalensis* among broad-leaf weeds and *Cyperus rotundus* in sedges. There was a significant variation in weed dry matter in each ICM module owing to different integrated weed management interventions. The least WDM was found in CA-based ICM modules while CT based ICM module exhibited higher WDM. Thus, differential weed competition led to variation in pigeonpea yield under different ICM modules with superiority of CA-based ICM modules. Overall, CA-based module with better integrated weed management (glypho-PP *fb* pendi-PE *fb* imaze-POE + 1 HWM) exhibited significantly higher seed (1.92 t/ha) and stalk yield (10.86 t/ha) over other ICM modules.

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Effect of tank-mix formulations of atrazine and new generation herbicides against complex weed flora of maize

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A field experiment was conducted on clay loam soil during *Kharif* 2017 at Instructional Farm, Rajasthan College of Agriculture, Udaipur to study the effect of tank mix formulations of atrazine and new generation herbicides against complex weed flora of maize and their effect on growth and yield. The experiment consists of thirteen weed control treatments comprising weedy check, atrazine 0.5 kg/ha (at 10, 15 and 20 DAS), atrazine 0.5 kg/ha + halosulfuron 0.09 kg/ha PoE (at 10, 15 and 20 DAS), atrazine 0.5 kg/ha + tembotrione 0.125 kg/ha PoE (at 10, 15 and 20 DAS) and atrazine 0.5 kg/ha + topramezone 0.025 kg/ha PoE (at 10, 15 and 20 DAS) laid out in randomized block design replicated thrice. The soil of experimental field was clay loam in texture, slightly alkaline in reaction, medium in organic carbon, available nitrogen, phosphorus and high in available potassium. The application of herbicides was done as per treatments with manually operated knapsack sprayer with flat fan nozzle. After calibration of sprayer, water volume used was 500 litres for post-emergence application of herbicide mixtures. The results revealed that the lowest weed density at 30 DAS (5.44/m^2) was recorded with tank mix application of atrazine 0.5 kg/ha + tembotrione 0.125 kg/ha PoE at 15 DAS. All the weed control treatments were also found significantly superior in reducing dry matter of monocot, dicot and total weeds compared to weedy check at 30 DAS (95.01 g/m^2). The minimum total weed dry matter at this stages (2.85 g/m^2) was observed under atrazine 0.5 kg/ha + tembotrione 0.125 kg/ha PoE at 15 DAS and it was closely followed by atrazine 0.5 kg/ha + topramezone 0.025 kg/ha PoE at 15 DAS (3.89 g/m^2). An application of atrazine 0.5 kg/ha + tembotrione 0.125 kg/ha PoE at 15 DAS resulted in maximum weed control efficiency of 96. 99% at 30 DAS. The maximum grain yield (5.24 t/ha) was observed with tank mix application of atrazine 0.5 kg/ha + tembotrione 0.125 kg/ha PoE at 15 DAS and it was at par with atrazine 0.5 kg/ha + tembotrione 0.125 kg/ha PoE at 20 DAS, both these treatments were significantly superior over rest of the treatments. The economic evaluation of the experiment revealed that maximum net returns (` 71009/ha) and benefit cost ratio (2.57) were obtained under application of atrazine 0.5 kg/ha + tembotrione 0.125 kg/ha PoE at 15 DAS.

Yield maximization and weeds in pigeonpea as affected by integrated crop management practices

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An experiment was conducted during *Kharif* season of 2014-15 at college of Agriculture, Babnapur, Vasantrao Naik Marathwada Agricultural University (M.S.). The weed management treatments were : IWM (pendimethalin at the rate of 0.75 kg/ha on 3 days after emergence + imazethapyr at the rate of 100 g/ha on 10-15 days after emergence of weeds + one hand weeding on 50 days after emergence) ; INM (FYM at the rate of 5 t/ha) ; IPM (indoxacarb 15.8 per cent EC at flowering at the rate of 375 ml/ha at 15 days after first spray; IWM + INM; IWM + IPM; IWM + INM + IPM and farmers' practice as control. Pigeonpea variety BSMR-853 in 90 x 30 plant spacing was tested in randomized block design was adopted. Fertilizers weed and pest control were applied as per the treatments. Weed flora observed in experimental field include prevailing monocot and dicot weeds in the area *viz., Digera arvensis, Parthenium hysterophorus, Sida ovate, Tridex procumbens, Sonchus asper, Acalypa indica, Euphorbia hirta, Euphorbia geniculata, Euphorbia microphora, Phaseolus filibulus, Acacia arabica, Commelina benghalensis, Cynodon dactylon, Allotrpsis cimicina, Dinebra retraflexa* and *Brachiaria eruciformis.* Minimum number of monocot and dicot weeds were observed in treatments receiving IWM + INM + IPM treatments. All weed free treatments brought significant reduction in weed dry matter as compared to unweeded. Results revealed that IWM + INM + IPM practice recorded maximum growth characters of pigeonpea *viz.*, plant height, number of functional leaves, number of branches per plant during all growth stages. Absolute growth rate was the highest in IWM + INM + IPM treatment, whereas, minimum was observed in IPM treatment. Highest weed control efficiency (95.61%) and lower weed index was recorded in IWM + INM + IPM treatment, whereas, lowest values in respect were recorded by INM treatment. IWM + INM + IPM practice recorded maximum yield attributes, *viz.* number of pods, weight of pods per plant of pigeon pea, however, test weight was not affected by treatments. Seed yield (15.65 t/ha), straw yield and biological yield of pigeonpea were also higher in weed free treatments. Gross and net monetary returns as well as B: C ratio followed the similar trend. Based on experimental findings it can be concluded that for optimum growth, productivity and increased net profit, it is essential to undertake timely integrated weed, nutrient and pest management practices in pigeonpea.

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Weed management in greengram in lateritic soil of West Bengal

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Green gram ranks third among the pulses after chickpea and pigeonpea in respect of production in India. Among the several constraints, associated with green gram productivity, weed infestation is considered to be the major one. The loss of yield in green gram due to weeds may go upto 68%. In view of severe infestation of annual and perennial weeds in green gram, the potential yield is generally not realized. Under this situation farmers need alternative production system using efficient weed management practices that offers a quick response to produce more. Keeping the above in view, the present study was conducted during summer season of 2018 at Agricultural Farm of the Institute of Agriculture, Visva- Bharati to study the efficacy of the herbicides against weed flora in green gram [*Vigna radiata* (L.) Wilczek]. The experiment was conducted with 8 treatments *viz*. pendimethalin at 1.0 kg/ha, imazethapyr at 75 g/ha, pre-mix of pendimethalin+ imazethapyr at 900, 1000 g/ha, pre-mix of imazamox+ imazethapyr 40, 50 g/ha, weed free and unweeded control. The experiment was laid out in a randomized block design with three replications. The green gram variety '*Samrat*' was sown in the first week of March and harvested in the end of May, 2018. Green gram was infested with 6 weed species out of which 3 were grasses, 2 broad-leaf and one sedge. Experimental results revealed that at 30 and 45 DAS application of pre-mix pendimethalin + imazethapyr at 900 and 1000 g/ha registered significantly lower density and biomass of grass, broad-leaf and total weed and was at par with pre-mix imazamox + imazethapyr at 50 g/ha. Weed free check registered significantly the highest seed yield of green gram. Among the weed management treatments, pre-mix of pendimethalin + imazethapyr at 900 and 1000 g/ha registered significantly higher seed yield over other treatments and was at par with pre-mix imazamox + imazethapyr at 50 g/ha.

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Evaluation of weed management practices in groundnut

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A field experiment was conducted consecutively for two *Kharif* seasons of 2016 and 2017, at Instructional Farm, College of Technology and Engineering, MPUAT, Udaipur. The objective was to find out proper weed management practices to enhance groundnut productivity in terms of quality and quantity. The experiment comprising combinations of six weed management treatments *viz.*, weedy check, weed free (up to 60 DAS), pendimethalin 750 g/ha as PE, oxyfluorfen 125 g/ha as PE, imazethapyr 100 g/ha as PoE (15 DAS) and quizalofop-ethyl 50 g/ha as PoE (15 DAS) with five phosphorus levels *i.e.* control, 20, 40, 60 and 80 kg/ha. The experiment was evaluated in the split-plot design with three replications keeping weed management practices in main and phosphorus levels in sub plots. The results of the present investigation indicate that in comparison to weedy check, all the weed management treatments reduced density and dry matter of narrow and broad-leaved as well as total weeds at 30, 45 DAS and harvest during both the years and on the pooled basis. Weed free up to 60 DAS was found significantly superior in reducing total weeds density and dry matter compared to weedy check and also accounted for the highest weed control efficiency (100%) at 30 and 45 DAS. Application of pendimethalin, oxyfluorfen, imazethapyr and quizalofop-ethyl recorded herbicidal efficiency index (1.59, 1.03, 1.72 & 0.79%), weed persistence index (0.90, 0.95, 1.04 and 0.93), crop resistance index (2.45, 1.94, 2.65 & 1.73) and weed index (3.55, 15.41, 2.86 and 19.15%), respectively. Among all the weed management treatments weed free resulted into the maximum weight of mature pods/plant (14.97) and 100-kernel weight (39.92 g). Consequently, weed free produced significantly higher pod (1.81 t/ha), kernel (1.18 t/ha), haulm (3.05 t/ha) and biological (4.86 t/ha) yields as well as harvest index (37.06%) compared to other treatments except for imazethapyr. Similarly weed free gave significantly higher protein content in kernels (23.67%), total chlorophyll content (1.67 mg/g), oil yield (0.55 t/ha) as well as N, P and K uptake by groundnut kernel, haulm and total uptake over the weedy check. Various weed management practices failed to cause any significant effect on plant stand, plant height and dry matter at 30 DAS, RGR between 20 and 40 DAS, shelling %, oil content in kernels as well as N, P and K content in pod and haulm and also soil available P. Amongst, weed management practices the significantly highest net return (` 64970/ha) was earned through post-emergence imazethapyr which was statistically at par with pendimethalin (` 64171/ha). The highest B:C of 2.60 was obtained with the application of imazethapyr followed by pendimethalin (2.55).

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Effect of post-emergence herbicides on weeds and yield of pigeonpea

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Pigeonpea being a *Kharif* season and long duration crop is highly infested with narrow and broad leaved weeds. Timely weed control is very essential for realization of yield potential of pigeonpea. Due to wider row spacing and initial slow growth of pigeonpea, weeds pose a major problem to its productivity. Manual and mechanical methods of weed control are quite effective, but they are costly and time consuming. However, due to frequent rains it becomes difficult to do hand weeding at proper time. In this condition farmers should use alternative options like chemical and cultural weed control methods which are most effective and cheaper. It is therefore, essential to use the post-emergence herbicides in conjuction with pre-emergence herbicides for the effective control of weeds. Presently, imazethapyr is a very effective post-emergence herbicide for controlling broad-leaf weeds in *Kharif* pulses including pigeonpea but its weed control efficacy has not been judged in combination with propaquizafop for wide spectrum weed control in different parts of the country.

A field experiment was conducted during *Kharif* season of year 2015, at product testing unit JNKVV, Jabalpur to study the efficacy of post-emergence herbicides for controlling weeds and on physiological parameters, growth, yield and yield components of pigeonpea. Total ten weed control treatments comprised of combined application of propaquizafop + imazethapyr at 62.5+75 and 100+100 g/ha and alone application of propaquizafop at 50, 62.5, 100 and 125 g/ha and fenaxaprop-p-ethyl (100 g/ha) and imazethapyr (100 g/ha) including hand weeding twice at 20 and 40 DAS and weedy check, were laid out in randomized block design with three replications. Data revealed that among the different herbicidal treatments, the combination of propaquizafop + imazethapyr at 100+100 g/ha was suitable for effective control of weeds. All herbicides increased total dry matter of plant and also increased important physiological characters like leaf area index, relative growth rate, crop growth rate and net assimilation rate. All herbicide treatments significantly improved yield and yield components like number of pods per plant, number of seeds per plant and harvest index as compared to control and maximum increase was found in propaquizafop + imazethapyr at 100+100 g/ha followed by their application at 62.5+75 g/ha treatment.

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Efficacy of pyroxasulfone 5% + pendimethalin 40% ready mixture for controlling weeds in soybean

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A field experiment was conducted during *Kharif* season of 2017 with eight treatments comprising of four doses of pyroxasulfone + pendimethalin mixture at 450, 675, 900 and 1125 g/ha, alone application of pyroxasulfone 100 g/ha and pendimethalin 750 g/ha as pre-emergence, hand weeding twice at 20 and 40 DAS including weedy check in randomized block design with 3 replications. The soybean crop '*JS 20-29*' was sown on July 17th 2017 with fertilizer dose of N 20, P_2O_5 60, K_2O 20 kg/ha. All the herbicidal treatments were applied one day after sowing (July 18th, 2017) and crop was harvested on October 28th 2017. The soil of the experimental field is clayey in texture, neutral in reaction (pH 7.2), medium in organic carbon (0.62) and available N (365 kg/ha), and available P (16.34 kg P_2O5/ha) and high in available K (327.16 kg K_2O/ha). In the experimental field, the dominant weed flora was *C. communis* which was closely followed by *P. niruri*. However, other monocot weeds like *C. rotundus* and *E. colona* and dicot weeds like *E. hirta* were also present in less numbers with soybean in weedy check plots. Among the herbicidal treatments, activity of pyroxasulfone + pendimethalin mixture 900 g/ha as pre-emergence, controlled most of the associated weeds. Weedy check had the highest weed biomass, which reduced significantly when weeds were controlled either chemically or mechanically. The lowest weed biomass was recorded under hand weeding treatment. Among the herbicidal treatments, application of pyroxasulfone + pendimethalin mixture at 900 and 1125 g/ha as pre emergence arrested the weed biomass production remarkably and proved superior. Complete weed control efficiency (100%) was noted under hand weeding treatment due to the lowest weed biomass production. Growth parameters were significantly superior under hand weeding treatment. Yield attributing traits *viz.*, pods per plant and seed index were also superior under treated plots as compared to weedy check in which these parameters were inferior. Both seed and haulm yields were significantly higher under all the plots receiving weed control measures than weedy check plots. Application of pyroxasulfone + pendimethalin at 900 g/ha recorded higher seed and haulm yields compared to application of pyroxasulfone + pendimethalin mixture at 450, 675, 900 and 1125 g/ha and alone application of pyroxasulfone (100 g/ha). The little expenditure was incurred under herbicidal treatments as compared to hand weeding twice. Through the monetary gross returns was higher under hand weeding twice but the application of pyroxasulfone + pendimethalin 900 g/ha gave the highest net monetary return and B:C ratio as pre emergence to soybean, indicating that application of pyroxasulfone + pendimethalin at 900 g/ha was suitable and profitable in soybean.

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Bioefficacy of herbicides for weed control in sesame

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A field experiment was conducted at Til Research farm, College of Agriculture, Tikamgarh during *Kharif*, 2016. The experiment was aimed to find out the suitable pre- and post-emergence herbicide or their combinations and determine the economic viability of herbicidal weed control in sesame. The experiment was laid out in randomized block design with twelve treatments replicated thrice. The treatments comprised of herbicide *viz*. pendimethalin at 750 g/ha as pre-emergence, post emergence herbicides like quizalofop-ethyl at 40 and 50 g/ha, fenoxaprop ethyl at 75 and 100 g/ha, sequential application of pendimethalin at 750 g/ ha *fb* quizalofop at 40 and 50 g/ha, pendimethalin at 750 g/ha *fb* fenoxaprop at 75 and 100 g/ha, pendimethalin *fb* one hand weeding at 20 DAS, two hand weeding at 15 and 30 DAS and weedy check. The sesame variety '*TKG-306*' was sown with seed rate of 5 kg/ha in rows 30 cm apart with fertilizer dose of 60 kg N, 40 kg P_2O_5 and 20 kg K_2O per hectare. The major weed species observed in the experimental area were *Cyperus rotundus, Cynodon dactylon, Eclipta alba, Leucus aspera* and *Mollugo pentaphyla*. The relative density of monocots was 63.73% at harvest stage while dicots were to the extent of 36.27%. All the herbicidal treatments and hand weeding significantly reduced the weed intensity as compared to weedy check. The lowest weed intensity, weed dry weight were registered under twice hand weeding at 15 and 30 DAS followed by pendimethalin *fb* one hand weeding at 20 DAS. Among herbicides, post-emergence herbicides fenoxaprop at 75 and 100 g/ha and quizalofop at 40 and 50 g/ha were registered significantly higher intensity as well as dry weight over pendimethalin followed by fenoxaprop at 75 and 100 g/ha and quizalofop at 40 and 50 g/ha. The maximum weed control efficiency was recorded under hand weeding twice (89.45%) followed by pendimethalin 750 g/ha *fb* hand weeding at 20 DAS (84.86%) and these treatments were at par with pre emergence application of pendimethalin at 750 g/ha *fb* post emergence fenoxaprop-ethyl at 100 g/ha at 20 DAS. Seed yield, stover yield and harvest index was significantly higher under hand weeding twice over all the herbicidal treatments and weedy check. Pendimethalin followed by hand weeding at 20 DAS produced significantly higher seed yield over all the herbicidal treatments, whereas, pre-emergence application of pendimethalin followed by quizalofop at 40 and 50 g/ha and fenoxaprop at 75 and 100 g/ha produced significantly higher seed and stover yield over alone application of quizalofop, fenoxaprop and pendimethalin. The gross and net monetary returns were minimum in weedy check plots whereas these were the maximum under hand weeding twice at 15 and 30 DAS followed by pendimethalin *fb* hand weeding at 20 DAS (` 49127/ ha) and pendimethalin at 750 g/ha *fb* fenoxaprop ethyl at 100 g/ha at 20 DAS (` 44022/ha). However, the benefit cost ratio was maximum under the application pendimethalin 750 g/ha *fb* fenoxaprop ethyl 100 g/ha (2.72) followed by pendimethalin 750 g/ha *fb* fenoxaprop ethyl 75 g/ha (2.70) and pendimethalin 750 g/ha fb quizalofop ethyl 50 g/ha (2.65).

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Pre- and post-emergence herbicides for weed control in soybean

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A field experiment was conducted College of Agriculture, Tikamgarh during *Kharif* 2016 to study the efficacy of pre- and post-emergence herbicides on weeds and yield of soybean. The experiment was laid out in Randomized Block Design with ten treatments replicated thrice. The treatments comprised of pre-emergence herbicides; clomazone at 1 kg/ha, pendimethalin at 1 kg/ha and alachlor at 1 kg/ha and post-emergence herbicides; imazethapyr at 75 g/ha, imazethapyr + imazamox at 70 g/ha, quizalofop-ethyl at 50 g/ha + chlorimuron-ethyl at 9 g/ha and quizalofop-ethyl at 50 g/ha, chlorimuron-ethyl at 9 g/ha and these treatments were compared with two hand weeding at 20 and 40 DAS and weedy check. The soybean variety '*JS-20-29*' was sown with seed rate of 80 kg/ha in rows, 30 cm apart with fertilizer dose of 20 kg N, 60 kg P_2O_5 and 20 kg K_2O/ha. The major weed species were *Cyperus rotundus, Cynodon dactylon, Brachiaria ramosa, Echinochloa crus-galli* and *Commelina benghalensis* as monocots whereas *Mollugo pentaphylla, Phyllanthus niruri* and *Digera* among dicots. All the herbicidal treatments and hand weeding reduced the weed intensity as compared to weedy check. Hand weeding twice registered the lowest weed intensity and weed dry weight among all the treatments, whereas among herbicides imazethapyr + imazamox proved potent in reducing the weed intensity and dry weight over all other herbicidal treatments. Application of post emergence imazethapyr was at par with quizalofop-ethyl + chlorimuron ethyl and these treatments registered significantly lower weed intensity and dry weight over pre emergence clomazone, pendimethalin and alachlor and post emergence quizalofop-ethyl and chlorimuron-ethyl. The WCE among herbicides and its combination varied from 24.82–61.47%. The highest weed control efficiency was recorded under hand weeding twice at 20 and 40 DAS (92.88%) followed by post-emergence application of imazethapyr + imazamox (61.47%), whereas it was lowest under pendimethalin (24.82%). The result of herbicidal weed control treatments on seed yield revealed that it was significantly the highest under hand weeding twice at 20 and 40 DAS (1033 kg/ha). Among the herbicides, imazethapyr + imazamox (825 kg/ha) registered significantly higher seed yield followed by quizalofop-ethyl + chlorimuron-ethyl (733 kg/ha) and imazethapyr (713 kg/ha) and these herbicidal treatments were found significantly superior over pre emergence application of clomazone (644 kg/ha), alachlor (630 kg/ha) and pendimethalin (586 kg/ha) and alone application of chlorimuron-ethyl (588 kg/ha). The maximum net monetary return was recorded under imazethapyr + imazamox (` 23951/ha) followed by hand weeding twice (` 22950/ha) whereas it was the lowest under pendimethalin (` 11718/ha) and weedy check (` 5394/ha). Benefit cost ratio was the highest under the application of imazethapyr + imazamox (2.75) followed by combined application of quizalofop-ethyl + chlorimuron-ethyl (2.39).

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Post-emergence herbicidal options for weed management in pulses

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Pulses are major source of plant protein and carbohydrates. Other nutrients like phosphorus, minerals, vitamin C, riboflavin and essential Amino acids are also major constituent of pulses. Since ages, pulses have been well integrated into the farming system of our country as the farmers could produce them by using their own seeds and family labour without depending much on external inputs. India is the largest producer (25% of global production), consumer (27% of world consumption) as well as importer (14%) of pulses in the world. The average yield of pulses in world is about 890 kg/ha, whereas in India it is around 650 kg/ha. As such, there is a gap of 240 kg or 27% approx. There are many reasons that contribute to lower yields of pulses in India. With the advent of Green Revolution, which promoted rice and wheat using external inputs and modern varieties of seeds, pulses were pushed to the marginal lands. This resulted in decline in productivity. Also, weed infestation is one of the major limiting factors for low productivity of pulse crops. Based on available literature that yield losses due to weeds vary from 20.3-53.4% in pigeonpea, 25.0-86.0% in greengram, 25.0-85.0% in blackgram, 40.8-68.3% in chickpea, 34.8-87.4% in lentil, 37.3-72.5% in field peas, 41.7-43.4% in garden pea, and 41.4-50.0% in french bean depending on kind of weed flora and intensity. A large number and diverse range of weed species belonging to grasses, broad-leaved and sedges dominate the pulse cultivation in different seasons of cropping. The critical period for crop-weed competition in pulses varies from 15-60 days after sowing. Weed management takes away nearly one third of total cost of production of field crops. In India, the manual/ mechanical method of weed control is quite popular and effective. Of late labour has become non-available and costly, due to intensification/diversification of agriculture and urbanization. The cost effective alternative is the use of herbicides. There are different selective herbicides used as pre-emergence in pulse crops to manage weeds. Usage of pre-emergence herbicides is popular in pulses and assumes greater importance in the view of their effectiveness in initial stages. Also efficacy of pre-plant incorporated and pre-emergence herbicides for weed control is reduced by various climatic and edaphic factors. The control of weeds emerge at later stage of critical period is also very important. Therefore post-emergence herbicides should be needed for effective management of weeds in pulses. But till now, main emphasis was given to control of grassy weeds only quizalofop-ethyl, fenoxaprop-p-ethyl and clodinafop-propargyl whereas, control of broad leaved weeds are equally important. Thus, there is urgent need of broad-spectrum post-emergent herbicides for pulses. However, few post-emergence herbicides like imazethapyr and imazethapyr + imazamox have shown effectiveness in weed management in some pulse crops. The use of post-emergence herbicides alone or in combination may broaden the window of weed management by broad spectrum weed control but still needs more investigation regarding post-emergent herbicidal options in pulses.

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Bio-efficacy of diclosulam 84% WG against weeds in soybean

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A field experiment was conducted during *Kharif* season of 2017 with nine treatments comprising of five doses of diclosulam at 13, 26, 39, 52 and 66 g/ha, alone application of imazethapyr 100 g/ha and pendimethalin 200 g/ha as pre-emergence, hand weeding twice at 20 and 40 DAS including weedy check, were laid out in randomized block design with 3 replications. The crop was sown on July 17th 2017 with soybean cv. '*JS 20-29*' with the fertilizer dose of N 20, P_2O_5 60, K_2O 20 kg/ha. All the herbicidal treatments were applied one day after sowing (18th July, 2017) and crop was harvested on October 28th 2017. The soil of the experimental field is clayey in texture, neutral in reaction (pH 7.2), medium in organic carbon (0.62) and available N (365 kg/ha), and available P (16.34 kg P_2O5/ha) and high in available K (327.16 kg K_2O/ha). In the experimental field, the dominant weed flora was *C. communis* which was closely followed by *E. colona*. However, other monocot weeds like *C. rotundus* and *E. colona* and dicot weeds like *Euphorbia hirta* were also present in less numbers with soybean in weedy check plots. Among the herbicidal treatments, activity of diclosulam 84% as pre-emergence, controlled most of the associated weeds. Weedy check had the highest weed biomass, which reduced significantly when weeds were controlled either chemically or mechanically. The lowest weed biomass was recorded under hand weeding treatment. Among the herbicidal treatments, application of diclosulam at 39 and 52 g/ha as pre emergence arrested the weed biomass production remarkably and proved superior. Weed control efficiency (100%) was noted under hand weeding treatment due to the lowest weed biomass production. Growth parameters were significantly superior under hand weeding treatment. Yield attributing traits *viz.*, pods per plant and seed index were also superior under treated plots as compared to weedy check in which these parameters were inferior. Both seed and haulm yields were significantly higher under all the plots receiving weed control measures than weedy check plots. Diclosulam at 39 g/ha recorded higher seed and haulm yields.

Both seed and haulm yields were significantly higher under all the plots receiving weed control measures than weedy check plots. Application of diclosulam at 39 g/ha recorded higher seed and haulm yields compared to application of diclosulam at 13, 26 and 52 g/ha and alone application of imazethapyr (100 g/ha). Less expenditure was incurred under herbicidal treatments as compared to hand weeding twice. Through the monetary returns was higher under hand weeding twice but the application of diclosulam 39 g/ha gave the highest net monetary return and B:C ratio as pre emergence to soybean, indicating that application of diclosulam at 39 g/ha as pre emergence was suitable and profitable in soybean.

Integrated weed management in pigeon pea – A review

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Pigeon pea is one of important grain legume crops in the world. Weeds in pigeon pea can be controlled effectively with hand weeding twice at 3 and 6 weeks after sowing. However, due to frequent rains and non-availability of labour it becomes difficult to do hand weeding at proper time. So there is a need to find effective weed control techniques using herbicides. In pigeon pea, initial six weeks period is the critical period of crop-weed competition. Therefore, weeds must be controlled during this period for obtaining high seed yields. Pre-emergence herbicides may help in checking weed growth during this period.

In this context, a field experiment was conducted at MPKV, Rahuri in 2003 and concluded that weed intensity and weed dry matter at harvest was significantly less in weed free treatment followed by fluchloralin as pre-planting incorporation 1.0 kg/ha *fb* glyphosate at 45 DAS. Higher weed control efficiency and lower weed index were recorded in pendimethalin pre-emergence 1.0 kg/ha *fb* glyphosate 1.0 kg/ha at 45 DAS. The seed yield of pigeon pea was maximum in weed free treatment followed by IWM treatment *viz.,* pendimethalin 1.0 kg/ha plus hand weeding at 45 DAS or pendimethalin pre-emergence 1.0 kg/ha *fb* glyphosate 1.0 kg/ha at 45 DAS.

A research experiment was conducted for seven years from 1998 to 2004 on a loamy sand soil to study the effect of weed management on weeds, growth and seed yield of pigeon pea and finding reported that, two hand weeding, pendimethalin in integration with hand weeding or ridging 50 DAS and paraquat in integration with hand weeding resulted in high weed control efficiency. Sole application of pendimethalin as pre-emergence at 0.45 or 0.75 kg/ha was less effective in controlling weeds. Integration of pendimethalin 0.45 kg/ha + hand weeding at 30 DAS plus + ridging 50 DAS provided the high weed control efficiency and produced the highest grain yields of pigeon pea in all the years of study.

Another field investigation was carried out during rainy seasons of 2010, 2011 and 2012 at Agricultural Research Station, Karnataka to evaluate the effect of pre- and post-emergent herbicides on weeds and productivity of pigeon pea and results indicated that, pre-emergence application of pendimethalin at 0.75 kg/ha *fb* one hand weeding at 50 DAS recorded significantly higher weed control efficiency similar to that of weed free plot and was at par with hand weeding twice at 25 and 50 DAS. Application of imazethapyr at 75 g/ha at 20 DAS *fb* paraquat at 0.40 kg/ha at 45 DAS found effective for controlling weeds and significantly higher seed yield. From the study of above review, it can be concluded that application of integrated weed management found to be effective for controlling weeds and getting higher seed yield of pigeon pea.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Bio-efficacy of acifluorfen + clodinafop propargyl on control of complex weed flora and productivity of greengram

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A field experiment was conducted during *Kharif,* 2017 at Instructional Farm of Rajasthan College of Agriculture, Udaipur which is situated at $24^0$35' N latitude and $74^0$42' E longitude. The region falls under the agro climatic zone IVa of Rajasthan *i.e.* Sub-humid Southern Plain and Aravali Hills of Rajasthan. The experiment was arranged in a randomized block design consisting of nine treatment combinations as in table replicated thrice. The predominant weed species were *Echinochloa colona*, *Commelina bengalensis*, *Trianthama portalacastrum*, *Parthanium hysterophorus* and *Digera arvensis* in monocot and dicot respectively, observed in the experimental field. Among the treatments, post-emergence application of aciflourfen + clodinafop propargyl 0.370 kg/ha significantly reduced the total weed dry weight (7.36 g/m^2) with 82.35 % WCE. No crop injury was observed with the different doses of aciflourfen + clodinafop propargyl used under the study. At 60 DAS and harvest revealed that lowest weed density was recorded with post emergence application of aciflourfen + clodinafop propargyl 0.370 kg/ha at 3-4 leaf stage and it was followed by pre-emergence application of pyroxasulfon 127.5 g + pedimethalin 1000 g/ha than followed by two hand weeding at 20 and 40 DAS.

Maximum weed control efficiency of grassy weed at harvest was recorded by two hand weeding at 20 and 40 DAS (85.80%), whereas weed control efficiency of broad-leaf (83.95 %) and total weeds (82.35 %) at harvest was found maximum with ready mix post-emergence application of aciflurofen + clodinafop 8% EC applied at 370 g/ha as post emergence at 3-4 leaf stage. The highest seed yield (1160 kg/ha) was obtained in post emergence application of aciflourfen + clodinafop propargyl 0.370 kg/ha at 3-4 leaf stage and the lowest (789 kg/ha) under weedy check. The yield loss due to uncontrolled growth of weeds as compared to weedy check was 47%. Herbicidal treatments resulted in considerably lower cost of cultivation compared with hand weeding at 20 and 40 DAS. The B: C ratio was found maximum (1.68) with post-emergence application of aciflourfen + clodinafop propargyl 0.370 kg/ha. Though, hand weeding recorded the highest seed yield but has lower BCR (1.64) because of higher cost involved in manual weeding. It was concluded that post-emergence application of aciflourfen + clodinafop propargyl 0.370 kg/ha was most effective in controlling of weeds and increasing seed yield with profitability in *Kharif* greengram.

Evaluation of proquizafop 2.5% + imazethapyr 3.75 % ready mixture against weeds in pigeonpea

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A field experiment was conducted to evaluate the bio-efficacy and suitable dose of proquizafop 2.5% + imazethapyr 3.75% ready mixture against weeds in pigeonpea during *Kharif* season of 2017-18 at Product Testing Unit, Department of Agronomy, JNKVV, Jabalpur. The ten treatments comprising of 3 doses of ready mixture of propaquizafop 2.5% + imazethapyr 3.75% (45+70, 50+75 and 55+80 g/ha), 2 doses of combined application of fomesafen 11.1% + fluazifop 11.1% (90+90 and 110+110 g/ha), alone application of propaquizafop (62.5 g/ha), imazethapyr (150 g/ha), pre-emergence application of pendimethalin (1000 g/ha), hand weeding twice including weedy check plot. The observation on weed density and weed biomass, growth and yield attributes traits and yield of pigeonpea. Finally, the economic variability of the treatments was also determined. The study revealed that *Echinochloa colona* (27.26%), *Phyllanthus niruri* (23.25%) and *Alternanthera philoxeroides* (16.55%) were most dominant. However, other monocot weeds like *Cyperus rotundus*, *Cynodon dactylon*, *Commelina benghalensis* and dicot weeds like *Cichorium intybus* were also present in less numbers in pigeonpea. Weedy check had the highest weed density and weed biomass, which reduced significantly when weeds were controlled either chemically or mechanically. Among the herbicidal treatments, application of propaquizafop + imazethapyr ready mixture at 55+80 g/ha as post-emergence arrested the weed density and weed biomass production remarkably and proved superior to its lower doses (50+75 and 45+70 g/ha), combined application of fomesafen + fluazeop-p-butyl (90+90 and 110+110 g/ha), alone application of imazethapyr (150 g/ha) and Post-emergence application of pendimethalin (1000 g/ha). However, none of the herbicidal treatments surpassed the hand weeding which had maximum weed control efficiency (94.95%). Plant population of pigeonpea at 30 DAS was not affected due to weed control treatments and was similar to that of hand weeding and weedy check plots. But combined application of fomesafen + fluazefop-p-butyl at 90+90 and 110+110 g/ha cause some phytotoxic and had lower plant population at harvest. Superior growth parameters (plant height, number of braches/plant and root nodules/plant); yield attributes (pods/plant, seeds/pod, seed index), higher seed and stick yields were recorded in plots receiving ready mixture of propaquizafop + imazethapyr at 50+75 followed by 55+80 g/ha to that of other doses of ready mixture of propaquizafop + imazethapyr and fomesafen + fluazefop-p-butyl (90+90 and 110+110 g/ha) and check herbicides propaquizafop at 62.5 g/ha, imazethapyr at 150 g/ha and pendimethalin at 1000 g/ha. The former treatments also found more remunerative as both attained higher values of NMR (` 43503 and 43425 /ha) and B: C ratio (2.45 and 2.43). Though hand weeding registered superior values of growth, yield attributes and yields but did not excel to former herbicidal treatments because of more cost of weed control (` 12000 /ha).

Bio-efficacy of pendimethalin (38.7% CS) as PPI against complex weed flora in chickpea

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A field experiment was conducted to evaluate the bio-efficacy of pendimethalin (38.7% CS) as PPI against complex weed flora in chickpea during *Rabi* season of 2017-18 at Product Testing Unit, Department of Agronomy, JNKVV, Jabalpur. The seven treatments comprising of 4 doses of pendimethalin (38.7% CS) at 575, 675, 775, 1350 g/ha as PPI, pre-emergence application of pendimethalin (38.7% CS) at 775 g/ha, hand weeding twice including weedy check plots. The observation on weed density and weed biomass, growth and yield attributes traits and yield of chickpea were recorded/computed. Finally, the economic variability of the treatments was also determined. The study revealed that *Cichorium intybus* (34.88%) and *Medicago denticullata* (31.27%) were most dominant. However, other monocot weeds like C*yperus rotundus (10.40%), Cynadon dactylon* (8.06%) and dicot weeds like *Cheopodium album* (15.37%) were also present in less numbers in chickpea. Weedy check had the highest weed density and weed biomass, which reduced significantly when weeds were controlled either chemically or mechanically. Among the herbicidal treatments, application of pendimethalin (38.7% CS) as PPI at 775 g/ha or at higher rate (1350 g/ha) arrested the weed density and weed biomass production remarkably and proved superior to its lower doses (575 and 675 g/ha) and application of pendimethalin (775 g/ha) as pre-emergence. However, none of the herbicidal treatments surpassed hand weeding which had maximum weed control efficiency (93.84 %). Plant population of chickpea at 20 DAS and harvest was not affected due to weed control treatments and was similar to that of hand weeding and weedy check plots. Superior growth parameters (plant height and number of the branches/plant); yield attributes (pods/plant, seed/pod, seed index), higher seed and stover yield attributes were recorded in plots receiving pendimethalin (38.7% CS) as a PPI at 775 g/ha followed by 675 g/ha to that of other doses of pendimethalin (38.7% CS) check herbicides as PPI and application of pendimethalin (38.7% CS) at 775 g/ha as check herbicides as PPI and application of pendimethalin (38.7% CS) at 775 g/ha as pre-emergence. The former treatments also found more remunerative as both attained higher values of NMR (` 50458 and 50456 / ha) and B: C ratio (2.69 and 2.68). Though hand weeding registered superior values of growth, yield attributes and yields but did excelled to former herbicidal treatments because of more cost of weed control (` 8000/ha).

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Weed growth and productivity of yellow sarson under different tillage and weed management practices in rice-yellow sarson-greengram cropping system

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Rice-yellow sarson-greengram is one of the predominant cropping systems in eastern India providing food, vegetable oil and protein. The main reason for lower productivity of yellow sarson is delayed sowing due to late harvesting of preceding long duration rice varieties. Proper utilization of short and mild winter is one of the major challenges for cultivation of *rabi* crops in eastern India. Zero tillage (ZT) can advance the sowing time through a single tractor operation using specially designed seed-cum-fertilizer drill. However, ZT practices are more advantageous when crop residues are retained on the soil surface, which serve as physical barrier towards emergence of weeds, moderate soil temperature, conserve soil moisture, add organic matter and solve the problem of air pollution arising due to large-scale burning of straw residues. Heavy weed infestation in initial years is the major hindrance in wide-scale adoption of conservation agriculture technologies. Keeping this in view, a field experiment was carried out during 2015-16, 2016-17 and 2017-18 at Agriculture Farm, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal to study the effect of tillage and weed management practices on weed growth and yield of yellow sarson in direct seeded rice- yellow sarson-greengram cropping system. Four tillage practices comprising of Conventional tillage (CT) (direct seeded rice) — CT (yellow sarson) — CT (greengram), CT (direct seeded rice) — Zero tillage (ZT) (yellow sarson) — ZT (greengram), ZT (direct seeded rice) — ZT (yellow sarson) — ZT (greengram), ZT + Residue (R) (direct seeded rice) — ZT + R (yellow sarson) — ZT + R (greengram) were allocated to the horizontal strip and three weed management practices *viz.*, Recommended herbicides (RH) (pendimethalin at 1.0 kg/ha followed by bispyribac-sodium at 25 g /ha in direct seeded rice, pendimethalin at 0.75 kg/ha each in yellow sarson and greengram), RH + hand weeding (HW) at 35 DAS, Unweeded control were assigned to the vertical strip in strip-plot design with three replications. Crop varieties '*MTU-1010*', '*B-9*' and '*Samrat*' were used for rice, yellow sarson and greengram, respectively. Yield attributes and seed yield of yellow sarson were recorded at harvest. The total number of weed species was 16 out of which *Digitaria sanguinalis*, *Cynodon dactylon* and *Cyanotis axillaris* among monocots and *Ageratum conyzoides*, *Spilanthes paniculata*, *Polygonum plebeium*, *Gnapahalium purpureum*, *Chenopodium album*, *Hedyotis corymbosa*, *Cleome viscosa*, *Solanum nigrum* and *Indigofera hirsuta* among dicots were predominant in yellow sarson. Conservational tillage (ZT+ R) along with RH + one hand weeding recorded lower values of total weed density (6.20, 6.43 and 2.0 no./m^2) and dry weight (1.22, 1.42 and 0.69 g/m^2) at 45 DAS and higher values of seed yield (1200, 1463 and 1338 kg/ha) of yellow sarson in first, second and third year, respectively. In second and third year, conservational tillage even with recommended herbicide alone exhibited higher weed control efficacy and registered significantly higher seed yield of yellow sarson than conventional tillage + RH +1 HW. Thus, conservation tillage along with recommended herbicide alone appeared to be a promising technique with respect to weed suppression and productivity of yellow sarson in rice-yellow sarson-greengram cropping system.

Impact of technological intervention in soybean through demonstration at farmers' fields

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Soybean, the number one oil seed crop in the world has recently occupied an important place in the edible oil and agricultural economy of the country. Its inclusion in the cropping system of the country in general and in the states of MP, Maharastra and Rajsthan in particular has resulted in the improvement of socio-economic status of the farmer and provided employment in village as well as in adjoining cities where soya based industries are located. One of the most important constraints of its low productivity is the weed infestation. Due to slow initial crop growth, proper soil moisture and congenial temperature, soybean is highly susceptible to weeds which reduce the yield to a tune of 35-67%. The conventional method of weed control (manual weeding) is expensive, time taking and tedious. At the same time because of the continuous rain during *Kharif* season, manual weeding becomes less effective, problematic and uneconomic. Therefore, different tested herbicides being used for controlling weed in soybean were demonstrated at farmers' fields to show the practicability and profitability with higher yield and income over farmer's practices.

Thirty five demonstrations on herbicidal weed control technology were laid out during *Kharif* of 2014 to 2015 in soybean at randomly selected two villages (Pola and Dhora) of Majhouli block, Jabalpur with the objective to show the performance and profitability of proven herbicides *viz.* chlorimuron ethyl (10 g/ha), chlorimuron ethyl (10 g/ha) + fenoxaprop-p-ethyl at (75 g/ha) and imazethapyr at (750 g/ha) on weed growth and productivity of soybean at farmers' fields. Fields were found infested with mixed weed flora. The herbicides under demonstration were found very effective in increasing grain yield of soybean by 23-40 per cent over farmer's practice depending upon the intensity and growth of weeds.

Benefit over the farmers practice were varied from ` 11,275 to ` 12,600/ha. During the demonstration, it was observed that some resourceful farmers were aware of the role of improved weed management technology in enhancing the overall crop productivity. It was also noted that farmer's practice, *i.e.* manual weeding being adopted at in appropriate stages of crop, which has no relevance over the crop yield and economy. During the survey of demonstrated area, it was realized that despite of the technological development in the field of weed science, the rational behind the conventional agricultural system is to derive the crop yield only through basic weed management strategy *i.e.* manual weeding owing to various social, economical and other constraints prevailing in the rural areas.

The demonstration at farmers field plays a very important role to disseminate recommended technologies because it is the only tool to test the potential of technologies at farmers level. Under demonstration some specific technologies related to weed management like use of proper herbicides, dose, time and method of application were undertaken in a scientific way.

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Integrated weed management in Summer greengram

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Among the pulses, greengram (*Vigna radiata* L. Wilczek) is one of the most important and extensively cultivated crop. It is grown during rainy and summer season. Being leguminous crop, poor crop establishment is often cited as a major constraint in greengram production (Kirchof *et al*. 2000). Among several other factors, proper weed management plays an important role for enhancing the productivity of greengram, as weeds compete for nutrient, water, light and space with crop plant during early growth period. Yield losses in greengram due to weeds have been estimated to range between 30-50% (Kumar *et al*. 2004). Thus, an experiment was conducted with an objective to identify a judicious combination of pre- and post-emergence herbicides and intercultural operations for managing weeds in greengram.

A field experiment was carried out during *Summer* season of 2013 at experimental farm (23°132' N, 79°582'E, and 390 m above mean sea level) of ICAR-Directorate of Weed Research, Jabalpur, Madhya Pradesh. The experiment was laid out in bigger plots (6.5 x 50 m for each treatment) with eight weed control treatments. Treatments comprised of pre-emergence (PRE) herbicides (pendimethalin 1000 g/ha and imazethapyr 100 g/ha); post-emergence (POST) herbicides (imazethapyr 100 g/ha and quizalofop-p-ethyl 60 g/ha); and hand weeding and hoeing as inter-culture operation. The post-emergence herbicides and intercultural operations were applied at 25 days after sowing (DAS).

Purple nut sedge (*Cyperus rotundus* L.) was the main dominant weed species found on experimental site. Other weeds were *Echinochloa colona* L. Link, *Paspalidium flavidum* Retz, *Dinebra retroflexa* Vahl. Panzer and *Eleusine indica*L. Gaertn among grasses, and *Ipomoea obscura* L. Ker Gawl, *Commelina diffusa* L., *Euphorbia geniculata* Orteg, *Convolvulus arvensis* L., *Physalis minima* L., *Alternanthera sessilis* L. DC., *Phyllanthus niruri* L., *Portulaca oleracea* L. and *Corchorus aestuans* L. among broad leaved weeds. Pendimethalin as PRE controlled the germination of grassy weeds. The imazethapyr as PRE had not any effect on the germination of grassy weeds, both the PRE herbicides were not effective to inhibit the germination of purple nut sedge. At 45 DAS, the imazethapyr 100 g/ha (PE) *fb* hoeing at 25 DAS was least effective on grassy weeds. The POST herbicides *i.e.* imazethapyr and quizalofop-p-ethyl, and inter culture operations effectively suppressed the growth of grassy weeds. The growth of purple nut sedge was controlled by the POST application of imazethapyr and quizalofop-p-ethyl. Significantly higher seed yield of greengram were recorded from PE application of pendimethalin 1000 g/ha *fb* POST application of either quizalofop-p-ethyl 60 g/ha or imzethapyr 100 g/ha at 25 DAS.

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Efficacy of herbicide and integrated nutrient management on growth and yield of French bean

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A field experiment was conducted to assess the effect of herbicides and integrated nutrient managements on weed dynamics, growth and yield of French bean at Banaras Hindu University, Varanasi during 2009 and 2010. The results revealed that the pendimethalin *fb* quizalofop-p-ethyl had significantly marked potential to minimized the weed dynamics of *Chenopodium album, Melilotus alba, Melilotus indica* and *Cyperus rotundus* significantly, resulted in marked reduction on total weed density (41.48 and 41.11 nos./m), weed dry weight (45.62 and 44.68 g/m) and weed index at all stages of crop growth during 2009 and 2010, respectively and showed higher weed control efficiency over the alone application of pendimethalin. Recommended dose + 200 kg/ha Wellgro Soil (dust) minimized broad leaves weeds (BLWs) over rest of the fertility levels but at par with RD + 300 kg/ha Wellgro Soil (dust) in respect of broad-leaves weeds (BLWs) weed density that resulted in enhanced weed index due to higher weed control efficiency over rest of the fertility levels during both the years of study. Significantly lower NPK removal by weeds at harvest recorded with pendimethalin *fb* quizalofop-p-ethyl under RD + 200 kg Wellgro Soil (dust), though remained at par with RD + 300 kg Wellgro Soil (dust). Root dry weight (g/plant), root nodules (number/plant), root nodule dry weight (mg/plant), nitrogen content in root, protein content, N, P, K, S content in grain and their uptake by crop and yield were produced with the application of pendimethilin at 1.0 kg/ha *fb* quizolofop-p-ethyl at 50 g/ha at 20 DAS proved its superiority over rest of the weed management practices. Among fertility levels the content of nutrients N% P% and S% were more in grains as compared to straw except K content, which follow reverse trends *i.e.* concentration of K was higher in straw as against in grains. RD + 300 kg/ha Wellgro soil (dust) recorded higher content of N, P, K and S in grains and straw by crops and was found significantly superior to rest of the treatments except RD + 200 kg/ha Wellgro soil (dust), where it was at par with each other's. However, 75% RD + 300 kg/ha Wellgro soil (dust) was also at par with 75% RD + 200 kg/ha Wellgro soil (dust) with respect to N, P, K and Scontent in grains and straw by crops. Similar trend was also found in protein content in grains. Whereas, CEC of roots was not influenced by any of the treatments. The grain yield kept on significantly increasing up to the RD + 200 kg/ha Wellgro soil (dust) fertility level.

Efficacy of pre- and post-emergence herbicides in sunflower

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A field investigation entitled "Efficacy of pre- and post-emergence herbicides in Sunflower (*Helianthus annuus* L.)" was carried out at the farm of Agronomy Department, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the *Summer* season of 2014. The investigation was carried out to study the relative efficacy of herbicides and cultural practices on weed control in sunflower as well as to study its effect on growth and yield of sunflower. The experiment was laid out in randomized block design with seven treatment replicated thrice. The treatments comprised of weed free, weedy check, mahna-042.5 kg/ha PE, pendimethalin 1.0 kg/ha PE, fluazifop-p-butyl 0.125 kg/ha PoE 15 DAS, quizalofop-ethyl 0.075 kg/ha PoE 15 DAS and fluazifop-p-butyl 0.125 kg/ha + quizalofop-ethyl 0.075 kg/ha PoE 15 DAS (Tank Mix).

The soil of experiment field was characterized as clay loam in texture, having slightly alkaline pH (7.8), moderate organic carbon status (0.40%), low nitrogen content (224.27 kg/ha), medium available phosphorus content (17.86 kg/ha) and high potassium status (384.25 kg/ha). Sunflower (TAS-82) was sown on 24th February 2014 at 60 x 30 cm spacing with 60:60:00 NPK kg/ha. The crop was harvested on 28th May 2014.

In the experiment field, predominant weed flora were *Chenopodium album*, *Portulaca oleracea*, *Tridax procumbens*, *Lagasca mollis, Euphorbia hirta, Euphorbia geniculata, Alternanathera triandra, Parthenium hysterophorus, Digera arvensis, Argemone Mexicana, Phyllanthus niruri* among the dicot weed, and *Cynodon dactylon, Cyperus rotundus, Eleusine indica* among the monocot. Weedy condition throughout the crop growth period caused 60.37% reduction in seed yield of sunflower. Among the herbicidal treatment, fluazifop-p-butyl 0.125 kg/ha + quizalofop-ethyl 0.075 kg/ha (Tank mix) was found to be effective in controlling weed across the crop growth period.

Among the various treatments under study, weed free recorded significantly higher values of major parameter whereas, in herbicidal treatments, the maximum growth and yield attribute *i.e.* capitulum diameter, seed filling per cent and seed weight per plant were recorded with treatment fluazifop-p-butyl 0.125 kg/ha + quizalofop-ethyl 0.075 kg/ha (Tank mix) and the next best treatment was application of pendimethalin 1.0 kg/ha. The same treatment recorded better weed control efficiency and lowest weed index. The nutrient uptake by weeds was more in weedy condition. However, total nutrient uptake by crop was observed maximum with tank mix application of fluazifop-p-butyl 0.125 kg/ha + quizalofop-ethyl 0.075 kg/ha. Tank mix application of fluazifop-p-butyl 0.125 kg/ha + quizalofop-ethyl 0.075 kg/ha was found most economical with maximum values of GMR (` 37102/ha), NMR (` 21000/ha) and B: C ratio (2.30).

Chemical weed management in brown sarson (*Brassica Compestris*) in temperate Kashmir

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Weed management is of great relevance in achieving full yield potential of Brown Sarson and chemical weed control is one of the options to control the weeds. With the advancement in weed research, new herbicides and their combinations are being developed by companies but their evaluation in terms of suppressing weeds and phyto-toxicity on crop has not been researched out in temperate Kashmir. With this view, a field experiment was conducted during *Rabi* 2016 and 2017 to evaluate herbicide weed management practices in Brown Sasron, apart from knowing the phyto-toxicity effect, if any. The experiment was conducted at Crop Research Farm of Faculty of Agriculture, SKUAST-K. The Experiment comprised of 8 treatments replicated thrice in a randomized block design. The treatments comprised of trifluralin (PPI) at 1400 g/ha, trifluralin (PPI) + propaquizafop (PoE) + pronamide (PoE) at 1200 + 100 + 2000 g/ha, trifluralin (PPI) + propaquizafop (PoE) + isoxaben (PoE) at 1200 + 100 + 500 g/ha, trifluralin (PPI) + haloxyfop-p-methyl (PoE) + pronamide (POE) at 1200 + 100 + 2000 g/ha, trifluralin (PPI) + haloxyfop-p-methyl (PoE) + isoxaben (PoE) at 1200 + 100 + 500 g ha, pendimethaline (PE) + isoproturon (PoE) at 1 kg/ha + 1 kg/ha weedy check weed free. The data on weed count in a quadrant of 50 x 50 cm were collected. Data averaged over three replications and two spots per replication. The density of weeds and their dry weight were recorded. The weed data is subjected to square root transformation before analysis. The crop data on yield attributes and yield were collected and relative economics of weed management practices were also worked out. The higher weed control efficiency (78.1% and 76.2% in 2016 and 2017, respectively) were observed in plots treated with trifluralin (PPI) + haloxyfop-p-methyl (PoE) + tronamide (PoE) at 1200 + 100 + 2000 g/ha followed by treatment trifluralin (PPI) + haloxyfop-p-methyl (PoE) + isoxaben (PoE) at 1200 + 100 + 500 g/ha. The weed population and weed dry weight in weedy check plots during 2017 and 2018 were 319.3-324.3 no/m^2 and 207.2–219.6 g/m^2, respectively. Brown Sarson treated with trifluralin (PPI) + haloxyfop-p-methyl (PoE) + pronamide (PoE) at 1200 + 100 + 2000 g/ha and trifluralin (PPI) + haloxyfop-p-methyl (POE) + isoxaben (PoE) at 1200 + 100 + 500 g/ha were significantly superior in checking weed growth and weed dry weight accumulation and eventually result in higher yield attributes and yield.

Efficacy of different herbicides on weed dynamics and yield of mungbean

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Among pulses, mungbean (*Vigna radiata* L.) is third most important pulse crop after chickpea and pigeon pea, which is cultivated in arid and semi-arid regions. It has high nutritive value with 25% protein, 1.3% fat, 3.5% mineral, 4.1% fiber and 56.7% carbohydrate. Among numerous factors, weed management plays an important role in improving the production from arid lands by saving moisture for crop utilization. Weeds compete with crop for space, nutrients, water and light and reduce the grain yield of mung bean by 23.5-45.8%. The conventional method of weed control by hoeing and hand weeding are very laborious, expensive and time consuming and needs to be often repeated at different intervals, therefore, the present investigation was planned to find out efficacy of different herbicides on weed dynamics and yield of mung bean (*Vigna radiata* L.).

A field experiment was conducted during two consecutive *Kharif* seasons of 2016 and 2017 at Agricultural Research Station, Mandor, Jodhpur. The soil of experimental field was sandy loam in texture, slightly alkaline in reaction (pH 8.2), low in organic carbon (0.13%) and available nitrogen (174 kg/ha), whereas medium in phosphorus (22.2 kg P_2O_5/ha) and high in available potassium (325 kg K_2O/ha). The experiment was laid out in randomized block design (RBD) comprising nine treatment combinations, *viz.* weedy check, pendimethalin 0.750 kg/ha (pre-emergence), pendimethalin 30 EC + imazethapyr 2 EC 0.750 kg/ha (pre-emergence), imazethapyr 10% SL 55 g/ha at 20 DAS, imazamox 35 WG + imazethapyr 35 WG 40 g/ha at 20 DAS, imazamox 35 WG + imazethapyr 35 WG 60 g/ha at 20 DAS, sodium aciflourfen 16.5% + clodinafop propargyl 8% 125 g/ha at 20 DAS, sodium aciflourfen 16.5% + clodinafop propargyl 8% 187.5 g/ha at 20 DAS and two manual weeding at 20 and 40 DAS with three replications.

Results of the investigation indicated that mannual hand weeding twice at 20 and 40 DAS recorded lowest weed dry matter and highest seed yield of cumin. However, among herbicidal treatments, sodium aciflourfen 16.5% + clodinafop propargyl 8% 187.5 g/ha at 20 DAS significantly reduced the dry matter of weeds (9.0 and 13.2 g/m^2) as compared to other treatments at 30 and 60 DAS, respectively. Due to effective weed control by sodium aciflourfen 16.5% + clodinafop propargyl 8% 187.5 g/ha at 20 DAS and pendimethalin at 0.750 kg/ha (pre-emergence) were recorded highest seed yield (1.06 and 1.0 t/ha, respectively), which were at par with each other and also showed equally effective as two manual weeding at 20 and 40 DAS.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Symbiotic parameters, growth, productivity of chickpea and weed control with integrated weed management

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Weeds compete with crop plants for moisture, nutrients and sunlight and thereby reduce yields. In chickpea, for controlling weeds, pre-emergence application of pendimethalin at 0.75 kg/ha or two hand weedings 30 + 60 days after sowing (DAS) have been recommended.

An experiment was conducted to study the effect of different doses of herbicides on weeds, symbiotic parameters, growth and productivity of chickpea. The field experiment was conducted during *Rabi* (winter) 2013-14 and 2014-15 at the research farm of Punjab Agricultural University, Ludhiana (30° 54´N, 75° 48´E, altitude 247 m), India. The soil of the experimental site was loamy sand, having pH 7.9, organic carbon 0.26%, available N 126.0 kg/ha, available P 19.1 kg/ha, and available K 158.5 kg/ha. A total rainfall of 263.2 and 221.0 mm was received during the crop growing season 2013-14 and 2014-15, respectively. Ten treatments, *viz.* pendimethalin 30 EC 0.75 kg/ha [pre-emergence (PE)], pendimethalin 30 EC 0.75 kg/ha (PE) + hand weeding (HW) at 25-30 DAS, pendimethalin CS 0.75 kg/ha (PE), pendimethalin CS 0.75 kg/ha (PE) + HW at 30-35 DAS, pendimethalin 30 EC + imazethapyr 2% (ready mix combination) 0.60 kg/ha (PE), pendimethalin 30 EC + imazethapyr 2% (ready mix combination) 0.75 kg/ha (PE), pendimethalin 30 EC + imazethapyr 2% (ready mix combination) 1.0 kg/ha (PE), pendimethalin 30 EC + imazethapyr 2% (ready mix combination) 1.0 kg/ha (PE) + HW at 30-35 DAS, HW at 30-35 DAS, and weedy check, were arranged in a randomized complete block design with three replications. These herbicides were sprayed using 500 litres of water per hectare. In the case of hand weeding, weeds were removed manually with a *khurpa*. In case of unweeded check plots weeds were allowed during the whole crop growing season. The crop was sown on 8 November during both the years. The sowing of variety 'GPF 2' was done in rows 30 cm apart using a seed rate of 45 kg/ha.

The major weed flora of the field constituted of *Oenothera drumundii*, *Lepidium sativum*, *Medicago denticulata*, *Rumex dentatus*, *Chenopodium album* and *Cyperus rotundus*. Various weed control treatments recorded lower number and dry weight of weeds than the weedy check. Integrated use of herbicides and HW improved the nodule number, dry weight of nodules and leghaemoglobin content over the sole use of herbicides. All the treatments of weed control improved the growth parameters and yield attributes over control. All the treatments of pendimethalin with or without hand weeding and imazethapyr recorded significantly higher grain yield over weedy check. Among the pre-emergence herbicide treatments, pendimethalin CS 0.75 kg/ha PE + one hoeing at 30-35 DAS, pendimethalin CS 0.75 kg/ha PE, pendimethalin 30 EC 0.75 kg/ha PE + one HW 25-30 DAS, pendimethalin 30 EC + imazethapyr 2% (ready mix combination) 0.75 as well as 1.0 kg/ha PE, pendimethalin 30 EC + imazethapyr 2% (ready mix combination) 1.0 kg/ha PE + HW at 30-35 DAS were found effective in controlling weeds and thereby increasing the grain yield of chickpea. Integrated use of herbicides and HW proved superior over sole use of herbicides in controlling weeds and improving grain yield. Further more, pre-mix combination of pendimethalin + imazethapyr was better than pendimethalin alone.

Biochemical parameters in summer greengram as affected by weed management and sulphur nutrition

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Greengram (*Vigna radiate* (L.)Wilczek) commonly known as "mungbean" is one of the important short duration pulse crops grown in India. Weeds cause severe losses in greengram due to its short stature and may causes severe losses in yield. Besides weeds, sulphur is one of the limiting factors which also affect its yield. Hence, an experiment was carried out with the objective to study the effect of weed management and sulphur nutrition on biochemical parameters of greengram at Instructional Farm, Rajasthan College of Agriculture, Udaipur during summer 2016. The experiment consisted of 5 weed-management treatments, *viz* pendimethalin + imazethapyr 0.75 kg/ha as pre-emergence (ready-mix), imazethapyr 100 g/ha as post-emergence, imazethapyr + imazamox 0.05 kg/ha (ready-mix) as post-emergence, hoeing and weeding 25 DAS , weedy check and 3 sulphur levels *viz.*, 0 kg/ha, 20 kg/ha , 40 kg/ha. The experiment was laid out in factorial randomized block design with 3 replications using greengram variety '*SLM-668*'. During the study important narrow leaf weeds were *Cynodon dactylon* (L.), *Echinochloa colona* (L.), *Brachiraria ramose* (L.), *Dactyloctinum aegypticum* (L.) and *Dinebra retroflexa* (L.) while important broad–leaved weeds were *Amaranthus viridis*, *Commelina benghalensis* (L.), *Digera arvensis* (L.) and *Trianthema portulacastrum*. Pendimethalin + imazethapyr 0.75 kg/ha (ready mix) recorded significantly the highest chlorophyll content at 40 and 60 DAS, protein content and grain yield at harvest with the corresponding values as 2.20 and 2.02 mg/g at 40 and 60 DAS, 23.09% and 0.697 t/ha compared to all the weed management treatments. Grain yield increased significantly under both 20 and 40 kg S/ha over control. The per cent increase in grain yield due to 20 and 40 kg S/ha was 13.0 and 24.2, respectively compared to control (0.5 t/ha). Application of 40 kg S/ha recorded the highest chlorophyll content of 2.15 and 2.01 mg/g at 40 and 60 DAS, respectively. Similarly sulphur application increased protein content by 13.85 and 7.17 % due to 40 and 20 kg/ha over control (20.36%), respectively. Pre-emergence application of ready-mix of pendimethalin + imazethapyr 0.75 kg/ha recorded significantly the lowest total weed dry matter at harvest (0.64 t/ha). Thus, research findings revealed that pre-emergence application of pendimethalin + imazethapyr 0.75 kg/ ha (ready mix) recorded the highest chlorophyll content, protein content and grain yield at harvest while, 40 kg S/ha significantly increased the chlorophyll and protein content and grain yield of greengram compared to 0 and 20 kg S/ha.

Evaluation of critical period of crop weed competition in mungbean under guava based agri-horti system in Vindhyan region

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Agri-horti system has emerged as a viable option for achieving cover on one hand and fulfilling the growing demand of food grain and fodder to human and livestock respectively on the other hand. This system fully utilizes the growing season and markedly increases the return per unit area per unit time. In India due to seasonal variability, there is wide opportunity for the selection of horticultural crops according to their climatic suitability. In the initial phase of orchard establishment, there is no economic return till trees start bearing fruits. There is ample scope for utilizing the interspaces of the fruit trees during the initial 5-6 years for growing of arable crops. Mungbean is potential options in guava based Agri-Horti system because it manages the weeds in interspaces and also provides economic return, However information on crop weed completion in mungbean is lacking under guava based Agri-horti system. Hence keeping this view an experiment on evaluation of critical period of crop weed competition on Mungbean under guava based agri-horti system in Vindhayan region was conducted at the Agricultural research Farm of Rajiv Gandhi south campus, Banaras Hindu University, Barkaccha,Mirzapur. This experiment was conducted during rainy (*Kharif*) season of 2016-17 in seven years old guava orchard which was planted at 7 x 7 m. Green gram *(Vigna radiata*) was sown as an intercrop. The experiment consisted eight treatments, *viz*. T_1-weed check, T_2-weedy free, T_3-weed free up to 15 days, T_4-weed free up to30 days, T_5-weed free up to 45 days, T_6-weedy up to 15 Days, T_7-weedy up to 30 days, T_8-weedy up to 45 days.

Lowest total weed density and biomass of Grasses (*Echinochloa colona, Cynodon dactylon, Digitaria sanguinalis), broad-leaf weeds (Trianthema monogyna, Parthenium hysterophorus, Commelina benghalensis),* sedges (*Cyperus rotundus*, *C.iria*) and lowest weed index was recorded in T_5 (weed free up to 45 days). Highest weed index was found in T_8 (weedy up to 45 days) as compared to other treatments. Among the tested treatments, T_5 (weed free up to 45 days) showed significantly higher growth attributes, *viz.* plant height, plant dry weight, number of leaves, number of branches and also showed significantly higher yield attributes and yield, *viz*. pod length, pods/plant, grains/pod, 1000 grain weight, grain yield, stover yield and harvest index of mung bean. The maximum benefit:cost ratio (2.25%) was obtained from T_5 (weed free up to 45 days), followed by T_2 (weed free), T_8 (weedy up to 45 days), T_7 (weedy up to 30 days), T_3 (weed free up to 15 days), T_6 (weedy up to 15 days) and lowest in weedy check. Based on the experimental findings, it can be concluded that for obtaining higher growth, yield attributes, yield and net return and benefit: cost ratio of mung bean under guava based Agri-horti system in vindhyan region. Crop should be kept weed free up to 45 days after sowing, which is critical period for crop weed competition.

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Evaluation of pre- and post-emergence herbicides in garden pea

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Pea has great potential for grain as well as vegetable purposes. It is grown in *Rabi* season in most of the parts of country. It is mainly grown for green pods as a fresh vegetable and is a rich source of protein, calcium, phosphorous, iron and vitamins. Being nitrogen fixing legume, this crop is useful for improving soil fertility and soil conservation. Also, early maturing cultivars of this crop fit well into crop diversifications under various crop rotations. The yield is affected by various factors and competition by weeds with garden pea is one of the major factors for reducing the yield and quality. Wider spacing in peas provides ample opportunities for weed infestation resulting in 20-66% yield losses. Crop is infested with both grassy as well as broad-leaved weeds. Hence effective weed management is pre-requisite to reduce losses caused by weeds and thereby improving productivity and profitability. Hoeing/hand weeding is generally adopted by farmers in field pea for weed control but it is time consuming, cumbersome and costly. Various pre-emergence herbicides have been evaluated for controlling weeds in garden pea at different parts of country. However, the information on effect of post-emergence herbicides or broad spectrum pre-emergence herbicides in controlling weeds in garden pea is meager especially under sub-tropical conditions of Jammu and Kashmir. Therefore, the present investigation was undertaken during the *Rabi* season of 2016-17 and 2017-18 to find out the effective dose of new broad spectrum pre-emergence and post-emergence herbicides in garden pea under sub-tropical conditions of Jammu and Kashmir. The experiment was laid out in Randomized Block Design with three replications. The herbicidal treatments consisting clodinafop-propargyl 60 g/ha and pinoxaden 50 g/ha as post-emergence, pendimethalin 1000 g/ha as pre-emergence, pendimethalin + imazethapyr 800, 1000 and 1200 g/ha as pre-emergence, imazethapyr 70 g/ha as pre-emergence, imazethapyr 60, 70 and 80 g/ha as post-emergence, imazethapyr + imazamox 60, 70 and 80 g/ha as post-emergence were compared with weedy check and weed free treatments. The pre-emergence herbicides were applied on next day of sowing and post-emergent herbicides were applied at 18-20 days after sowing. On the basis of two years pooled data, weed management treatments had significant effect on weed density and weed biomass at 25 and 50 days after sowing. Among the herbicidal treatments, pendimethalin + imazethapyr at 1250 g/ha or pendimethalin + imazethapyr at 1000 g/ha as pre-emergence or significantly reduced grassy and broad-leaved weed density and biomass and recorded significantly higher plant height, plant dry matter, number of nodules, number of pods and green pod yield as compared to weedy check. Imazethapyr + imazamox at 60, 70 and 80 g/ha as post-emergence showed slight yellowing in leaves of pea but these recover at later stages. However, highest net returns and B: C ratio was recorded in pendimethalin + imazethapyr 1000 g/ha as pre-emergence.

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Adoption of improved crop management practices by the pea growers

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Pea (*Pisum sativum* L.) family Leguminoceae is one of the important vegetable and pulse crops of India and is the inseparable ingredient of vegetarian diet and a cheapest source of dietary protein (22.5%), carbohydrate (62.1%), fat (1.8%), vitamins (riboflavin, thiamin *etc.*) and minerals (calcium iron). Madhya Pradesh is the second largest pea producer state in India, covering an area of approximately 57.80 thousand hectares with production of about 607.00 metric tons and Madhya Pradesh is the second largest pea producer state in India. Pea is grown over an area of 57.80 thousand hectares with a production of about 607.00 metric tons. The productivity of pea is about 1.05 t/ha. Seeing the economic and nutritional importance of pea, the present study was undertaken in Shahpura and Patan blocks of district Jabalpur, which is the largest pea producing district in Madhya Pradesh, to know whether the pea growers are adopting the improved production technology or not and up to what extent, *i.e.* to analyze the adoption behavior of pea growers. It was revealed from the study that, the attributes responsible for high extent of adoption of new technologies were proper production practices, weed and disease management, education, size of land holding, experience of pea growing, income, knowledge level, scientific orientation, source of information, extension participation, market orientation, training need. Field pea are poor competitors with weeds in the early seedling stage. Weeds should be control by 1-2 weeks after crop emergence. Generally, apply broad-leaf herbicides to small weeds for most effective control, and small pea plants to reduce crop injuries. Good weed control is essential in the pea crop, since it is not very competitive and is easily dominated by weeds. Efficient control will ease combining and facilitate rapid drying in addition to increasing yield. A number of pre- and post-emergence herbicides are available. Pre-emergence herbicides are best applied to a rolled, clod free, moist seedbed. General control of annual broad leaved weed can be achieved. Pre-emergence with a soil applied residual herbicide or when weeds and crop have both emerge with a foliar applied post emergence herbicide.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Effect of herbicides and their ready-mix combinations on weeds and productivity of black gram

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Black gram (*Vigna mungo* L. Hepper) is one of the most important pulses crop, grown across the India. Among the various factors responsible for its poor productivity in the state, heavy weed infestation is the foremost. The continuous rainfall during the season makes the manual weeding impracticable. Pre-emergence herbicide application of pendimethalin has been recommended to control weeds in this crop but this herbicide has limited period of its application and it does not control all types of weeds effectively. It cannot be used as post-emergence herbicide in case of failure of spray at proper time. However, all types of weeds may not be controlled by the use of a single herbicide in a particular crop; hence, herbicides with differential selectivity can be applied sequentially. But it involves application in two rounds, resulting in enhanced cost. Therefore, mixing two herbicides and applying them simultaneously widens the spectrum of weed control, saves time and application cost and reduces impact of herbicides on environment. Therefore, the field experiment was conducted at the research farm of regional research sub-station at Berthin, Bilaspur, Himachal Pradesh during *Kharif* season of 2015 to study the different herbicide combination and their influence on weeds in black gram. Twelve weed control treatments, *viz.* imazethapyr at 70 g/ha (pre-emergence), imazethapyr at 80 g/ha (pre-emergence), imazethapyr at 70 g/ha (3-4 leaf stage), imazethapyr at 80 g/ha (3-4 leaf stage), ready mix combination of imazethapyr + imazamox 70 g/ha (pre-emergence), ready mix combination of imazethapyr + imazamox 80 g/ha (pre-emergence), ready mix combination of imazethapyr + imazamox 70 g/ha (3-4 leaf stage), ready mix combination of imazethapyr + imazamox 80 g/ha (3-4 leaf stage), pendimethalin at 1000 g/ha, ready mix combination of imazethapyr + pendimethalin 1000 g/ha (pre-emergence), hand weeding twice (25 and 45 DAS) and weedy check were tested in randomized block design with three replications.

Echinochloa colona, Dactyloctenium aegyptium and *Cyperus iria* were the major weeds constituting 51, 34 and 17%, respectively, of total weed flora at 60 DAS. Grassy weeds were predominated in experimental field. Ready mix combination of imazethapyr + imazamox 80 g/ha pre-emergence and imazethapyr + imazamox 70 g/ha pre-emergence were comparable and resulted in significantly lower population and dry weight of *Echinochloa colona, Dactyloctenium aegyptium, Cyperus iria* and total weeds. Uncontrolled growth of weeds reduced black gram yield by 68.1% under low hill conditions of Himachal Pradesh. It was concluded that application of ready mix combination of imazethapyr + imazamox at 80 g/ha was an effective alternative to pendimethalin or manual weeding or imazethapyr alone or even its post-emergence application in providing satisfactory control of mixed weed flora in black gram and giving higher productivity and profitability

Demonstration of integrated crop management in groundnut through cluster approach for enhancing the yield

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Groundnut is the sixth most important oilseed crop of the world, fourth most important source of edible oil and third most important source of vegetable protein. Groundnut is cultivated in an area of about 15000 hectares in Dharmapuri District. Besides moisture stress, lack of knowledge on the availability of drought tolerant varieties, prevalence of nutrient deficiency, improper weed management, pest and disease also affect the groundnut under rainfed condition. Hence, to create awareness among the farmers, cluster frontline demonstration was taken up in twenty five farmers' holding of Dharmapuri district during 2017-18 *Kharif* season. The integrated crop management (ICM) practices including cultivation of drought tolerant, short duration, groundnut variety '*Dharani*' (TCGS 1043), integrated weed management, integrated nutrient management, integrated pest and disease management practices were demonstrated and compared with local check at cluster villages of Naripalli, Chinnampalli, Athigarapatty and Belrampatty in Dharmapuri district. In the cluster villages, the total number of weed species present in the demonstration field was eight under three categories *viz*. five broad-leaved weeds, two grasses and one sedge. The species under grass category were *Panicum repens* and *Dactyloctenium aegyptium* and those under broad-leaved weeds were *Trianthema portulacastrum*, *Parthenium hysterophorus*, *Digera arvensis*, *Tephrosia purpurea* and *Ageratum conyzoides* and only one sedge weed *Cyperus rotantus* was presented in the demonstration fields. Species wise data of the weed composition revealed that *Panicum repens* among the grassy weeds and *Trianthema portulacastrum* among the broad-leaved weeds were the most dominant at 40 days after sowing. The grassy weed *Panicum repens* was the most predominant (28.7%) among the total weed species present followed by *Trianthema portulacastrum* (20.2%). The demonstration fields were mostly dominated by broad-leaved weeds, which comprised of about 42.7 per cent of the total weed population. Among the selected farmers, 75% revealed that they are ready to adopt new varieties and use of seed treatment for the disease and insect pest protection. The integrated crop management strategies were followed by 35 per cent of beneficiary farmers. Most of the farmers take the plant protection measure after noticing the incidence of pest and diseases. More than 60 per cent of the beneficiary farmer informed that they will spread the variety to fellow farmers. Results revealed that demonstration of groundnut variety '*Dharani*' with integrated weed management practices registered higher yield of 1.96 t/ha and farmers' practice recorded lower yield of 1.43 t/ha. In groundnut, integrated crop management demonstrations have given 37 per cent higher pod yield as compared to local check. Farmers earned higher net return of ` 29,981/ha through the demonstration and ` 19,922/ha with local check. BCR was higher in all technology demonstrations (2.02) as compared to their local check (1.56). In Dharmapuri District, more than 70 per cent of farmers adopted the integrated crop management technologies in groundnut and they will recommend to the neighbouring farmers.

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Liquid biofertilizer and inorganic nutrients effect on physiological, quality parameters and productivity of *Kharif* groundnut

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Persistent nutrient depletion is posing a greater threat to the sustainable agriculture. Therefore, it becomes imperative to explore the most effective combination of inorganic fertilizers and liquid biofertilizers for sustaining the soil fertility and producing quality products. Hence, a field trial was conducted during *Kharif* 2017 at College of Agriculture, Gwalior with a view to assess the effect of fertility levels and biofertilizers on quality and physiological parameters of groundnut. Experiment laid out in split plot design set up comprised of 12 treatment combinations replicated thrice in fixed plots having four fertility levels *viz.* 25, 50, 75 and 100% recommended rate of fertilizers as main plots and three bioformulations *viz.*, no bio-formulations (B_1), NPK liquid formulation + Zn solubilizing bacteria (B_2) and bio-grow application (B_3) as sub plots. The recommended dose of NPK for groundnut is 20-60-20 kg/ha and were applied in full as basal dose through urea, single super phosphate and muriate of potash, respectively at the time of sowing. The gross plot size was 5.0 x 4.5 m and the seed of JGN3 cultivar of groundnut at 100 kg/ha was sown on 6th July 2017. Soil has low initial N (208.7 kg/ha), medium P (13.1 kg/ha) and high K (268.8 kg/ha) contents. It contained 0.56% organic carbon with the pH of 7.3 and electrical conductivity 0.37 dS/m. To prevent seed borne diseases, the kernels were treated with the fungicides dithane M-45 2 g/kg seed, bavistin at 1 g/kgseed and with biofertilizers as per the treatments before sowing.

A high incidence of thrips and bud necrosis virus was noticed which was controlled by treating the crop with an insecticide Dimethoate 30 EC at 2 ml/litre water at 45 DAS. Chlorpyrifos at 1.5 L/ha was incorporated in soil to control termite infestation before sowing and at 40 DAS. Imidaclorpid (1 ml/litre water) + mancozeb (2 g/litre) at the time of disease occurrence were applied against fungal diseases such as early blight, late blight and stem rot. Three irrigations were provided to groundnut and two hand weeding were done to control the weeds. Five plants in each plot were selected randomly for observations on quality and physiological parameters. Observations were made on leaf area index, crop growth rate (g/m^2/day), relative growth rate (g/g/day) at 30, 60 and 90 DAS and quality parameters were analysed in groundnut kernels at harvest. Application of bioformulation as liquid NPK with Zn solublizing bacteria resulted in better physiogical growth and highest kernel (2.114 kg/ha) and haulm yield (6676 kg/ha) of groundnut crop. Same treatment also resulted in highest protein (4.4 kg/ha) and oil yield (6.7 kg/ha). Application of 100% RDF with bioformulation as NPK liquid formulation + Zn solubilizing bacteria produced highest LAI, CGR, RGR values as well as protein and oil yield of groundnut followed by 100% RDF with biogrow application.

Response of *Kharif* groundnut to biofertilizer and inorganic sources of nutrients

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Despite economic significance and maximum yield of groundnut, very meager information is available on the combined use of biofertilizer and inorganic sources. Thus, there is an urgent need for steeping use of major, secondary and micronutrients which can be overcome by the use of bio fertilizers. Hence, an experiment was conducted during *Kharif* 2017 at College of Agriculture, Gwalior to study the response of groundnut to biofertilizer and inorganic sources of nutrient. It was laid out in split plot design, replicated thrice in fixed plots and the test variety of the crop groundnut (JGN 3) was used with seed rate of 100 kg/ha. Four fertility levels as 25, 50, 75 and 100% recommended rate of fertilizers with three bioformulations as (B_1) no bio-formulations, NPK liquid formulation + Zn solubilizing bacteria (B_2) and biogrow application (B_3). Soil has low initial N (208.7 kg/ha), medium P (13.1 kg/ha) and high K (268.8 kg/ha) contents. It contained 0.56% organic carbon with the pH of 7.3 and electrical conductivity 0.37 dS/m. The recommended dose of NPK for groundnut is 20-60-20 kg/ha. The N, P and K fertilizers were applied in full as basal dose through urea, single super phosphate and muriate of potash, respectively. Before sowing, the kernels were treated with the fungicides dithane M-45 at 2 g/kg seed, bavistin at 1 g/kg seed and with biofertilizers as per the treatments. There was high incidence of thrips and bud necrosis virus thus, to control thrips infestation the crop was treated with an insecticide dimethoate 30 EC at 2 ml/litre water at 45 DAS. Chlorpyrifos at 1.5 L/ha was incorporated in soil to control termite infestation before sowing and at 40 DAS. Imidacloprid (at 1 ml/3litre water) + Mancozeb (at 2 g/litre) at time of disease occurrence were applied against the incidence of fungal diseases as early blight, late blight and stem rot. Three irrigations were provided to groundnut and two hand weedings were done to control the weeds. Five plants in each plot were selected randomly and tagged for taking various biometric observations. Observations were made on dry weight of pods/plant (g), number of mature pods/plant, test weight (g), number of primary branches/plant, number of nodules/plant at 30, 60 and 90 DAS and dry matter accumulation at 30, 60 and 90 DAS. Pods were sun dried up to 9% moisture level. Statistical analysis of the data was carried out using analysis of variance technique. Application of bioformulations as NPK liquid formulation with Zn solubilizing bacteria and biogrow resulted in 9.8, 8.6, 14.5% and 8.0, 4.3, 7.2% increase in haulm, grain yield and net returns, respectively compared to no bioformulation application. Application of 100% RDF with bioformulation as NPK liquid formulation + Zn solubilizing bacteria produced highest number of branches/plant, number of nodules and dry matter accumulation at 30, 60 and 90 DAS followed by 100% RDF with biogrow application. Similarly, same treatments also resulted in highest yield attributes, yield and net returns of groundnut crop.

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Effect of herbicide with surfactant to enhancing the weed control efficiency, nodulation and yield of soybean

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A field experiment was conducted to study the efficacy of different post-emergence herbicides and their combinations to control the weeds in soybean during *Kharif* season of the year- 2013 to 2017. Application of quizalfop-ethyl + chlorimuron and fenoxaprop-p-ethyl + chlorimuron along with surfactant at 15 days after sowing is highly selective of herbicide for control of both broad and grasses weeds in soybean crop. The weed population recorded at 45 DAS reveled that post-emergence application of quizolphop-ethyl at 50 g/ha + chlorimuron at 6 g/ha. Reduced the population of weed (8/m^2), lowest weed dry matter (2.3), weed index (0) and highest weed control efficiency (92.9%) and grain yield (1.77 t/ha.) was found followed by application of fenoxaprop p-ethyl at 50 g/ha + chlorimuron at 6 g/ha (92.1%, 1.0 and 1.73 tha), respectively as compared to other treatment. They minimized the losses caused by weed growth their by leading to improvement in water, air, and nutrition of crop which ultimate enhance nodulation *i.e.* nodule number, nodule diameter and nodule weight (52, 5.0 mm and 187.2 mg/plant) respectively in treatment T_9 followed by T_8 as compared to all treatments its resulted higher yield was observed in this treatments. Quizalfop-ethyl and fenoxaprop-p-ethyl + chlorimuron along with surfactant is highly comparable with in terms of price and yield compared to other methods of weed control conspicuously two hand weeding. This combination is recently recommended for the control of both broad and narrow leaved weed where of major infestation in this crop. These chemical at their recommended doses source method and time of application are not harmful to present and seceding crops.

Impact of frontline demonstration of weed management practices on productivity and profitability of blackgram in Madhya Pradesh

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Blackgram (*Vigna mungo*), is a bean grown in the Indian subcontinent.India is the world's largest producer as well as consumer of black gram. It produces about 1.5 to 1.9 MT of black gram annually from about 3.5 m ha of area, with an average productivity of 600 kg/ha. The main objective of front line demonstration was to show the worth or value of the technology. The present study was carried out at KrishiVigyan Kendra, Raisen to evaluating the performance of improved cultivars with scientific package and practices on production, productivity and profitability of blackgram. Frontline demonstrations were conducted during 2017-18 with evaluation the performance of Imazethapyr and PU-31, variety of blackgram in Gairatganj block of the district and record the feedback information of farmer's. The results revealed that average yield of blackgram under frontline demonstrations were 0.72 t/ha as compare to 0.46 t/ha recorded in farmer's practice, average yield increase of 56 per cent and net return of 10250.00 and ` 3920.00/ha, respectively. It was observed that the benefit cost ratio (B: C) of recommended practice were 1.89 as compared to 1.39 in farmer's practice during year of the study. Therefore, the results clearly indicates that the use of improved varieties and package and practices with scientific intervention under frontline demonstration programme contribute to increase the productivity and profitability of pulses in Madhya Pradesh state.

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Distribution of *Mikania micrantha* in coffee growing areas of karbi anglong district of Assam

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India is the seventh largest producer of coffee in the world and contributes 3.81% and 4.48% of world coffee production and export, respectively. In Assam, coffee cultivation covers an area of 1249 ha and is confined in Chirang, Karbi Anglong and Dima Hasao districts. Coffee cultivation also has the potentiality for expansion in the foot hill regions of Lower Brahmaputra Valley and Hill agro-climatic zones of the state. Among the hurdles in coffee cultivation in NE India including Assam, weed management is one of the most critical ones, and amongst the most common weeds, *Mikania micrantha* H.B.K. is the highest troublesome species. To quantify the infestation of the weed in and around coffee growing areas, a survey was undertaken in five coffee plantations and 28 locations of other plantation crops covering an area of 355 km^2 in Karbi Anglong district of Assam. At each plantation area, a 1.0 ha plot was selected and abundance of*M. micrantha* was assessed from altogether 50 spots placing 1 x 1 m quadrates randomly. The number of stalks of *M. micrantha* counted in each quadrate was considered as individual plants. These numbers were assigned grades to indicate a ranking on the basis of abundance of *M. micrantha*. The *M. micrantha* infestation was negligible to low in coffee plantations which received two rounds of manual weeding whereas the infestation was moderate to high where only one manual weeding or no weeding was attended. In the moderately dense forest where tree canopy coverage was 40-70%, *M. micrantha* infestation was practically zero while in open forest, the infestation grade of the weed was quite high. It could be ascribed to low light availability in moderately dense forest. *M. micrantha* grows best in habitats having good light conditions combined with vertical supporting structures, such as trees and shrubs. Bamboo grooves in the study area was nothing but the secondary forests and mostly composed of *Dendrocalamus hamiltonii, Bambusa balcooa, etc*; *M. micrantha* was recorded only in two plots out of total eight sites of bamboo forests, that too with negligible infestation. Similar negligible infestation of *M. micrantha* was also noticed in mature tea with moderately dense canopy coverage. Higher magnitude of *M. micrantha* infestation in other plantation crops adjacent to coffee estates were the major sources of seeds for repeated migration of the weed to coffee. Among the coffee estates surveyed, the highest infestation of *M. micrantha* was observed in the estates surrounded by open forests which served as a good seed source of the weed. The study revealed that *M. micrantha* infestation might become severe in plantation crops if proper management practices were not adopted. Maintenance of closer canopy coverage may be one of the effective practices to get rid of the invasive weed. Presence of large numbers of poorly managed other plantation crops were the major sources of *M. micrantha* seeds for dispersal to the coffee estates.

Theme 9

Weed management in cash crops and minor crops

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Efficacy of new generation herbicides on weed control and forage yield of forage maize

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The field experimental was conducted at AICRP on forage crops and Utilization, Mahatma Phule Krishi Vidyapeeth, Rahuri, Tal. Rahuri, Dist. Ahmednagar, Maharashtra on effect of new generation herbicides on weeds and forage yield of forage maize during *Kharif* -2017. The experiment was laid out in randomized block design with three replications comprised of ten treatment combinations *viz*. Tembotrione 120 g/ha at 20 DAS, topramezone 35 g/ha at 20 DAS, tembotrione 120 g/ha + atrazine 250 g/ha at 20 DAS, topramezone 35 g/ha + atrazine 250 g/ha at 20 DAS, atrazine 1000 g/ha pre-emergence, pendimethalin 1000 g/ha pre-emergence, atrazine 750 g/ha + pendimethalin 750 g/ha pre-emergence, 2,4-D 0.5 kg/ha at 20 DAS,– hand weeding at 20 and 40 DAS and weedy check. The forage maize variety used was '*African Tall'*. The results revealed that among the weed control treatments, weed count per/m^2 of monocot weeds and dicot weeds and total weeds were recorded significantly lower at 30 and 60 DAS, respectively with tembotrione 120 g/ha + atrazine 250 g/ha at 20 DAS. It was at par with application of topramezone 35 g/ha + atrazine 250 g/ha and atrazine + pendimethalin 750 g/ha each at 20 DAS**.** The total weed dry weight (23.33 and 26.00 g/m^2) at 30 and 60 DAS, respectively was recorded significantly lower in the application of tembotrione 120 g/ha + atrazine 250 g/ha at 20 DAS. However, it was at par with topramezone 35 g/ha + atrazine 250 g/ha and atrazine + pendimethalin 750 g/ha each at 20 DAS. The weed control efficiency was significantly higher in hand weeding. While, total weed control efficiency were recorded significantly higher at 30 DAS and 60 DAS, respectively in tembotrione 120 g/ha + atrazine 250 g/ha at 20 DAS. However, it was at par with topramezone 35 g/ha + atrazine 250 g/ha and atrazine + pendimethalin 750 g/ha each at 20 DAS. On the basis of data on weed dynamics and yield in maize, it was concluded that among the weed control treatments, green forage yield (58.40 t/ha), dry matter yield (13.52 t/ha), crude protein yield (1.35 t/ha)**,** gross monetary returns (` 1,16,799/ha/yr), net monetary returns (` 90,534/ha/yr), and B:C ratio (4.45) were obtained significantly higher with the application of tembotrione 120 g/ha+ atrazine 250 g/ha at 20 DAS. It was at par with application of topramezone 35 g/ha+ atrazine 250 g/ha at 20 DAS and atrazine + pendimethalin 750 g/ha each at 20 DAS.

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Integrated weed management in *Kharif* greengram

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The present investigation was carried out at Post Graduate Research Farm, Agronomy section, College of Agriculture, Dhule, during the *Kharif* season of year 2017. Experiment consisted of 8 treatments laid out in randomized block design with three replications. The treatment included, weed free, weedy check, pendimethalin 580 g/ha as PE, imazethapyr 75 g/ha as PE, pendimethalin 1.0 kg/ha as PE + imazethapyr 50 g/ha as PoE, pendimethalin 580 g/ha as PE + HW at 20 DAS, imazethapyr 75 g/ha as PE + HW at 20 DAS and imazethapyr 75 g/ha at 15 DAS as PoE. Among the different weed control treatment, integrated weed management treatment *i.e.* spraying of pendimethalin at 580 g/ha as PE *fb* one hand weeding at 20 DAS exhibited less weed flora, weed intensity and weed dry weight which was at par with imazethapyr 75 g/ha as PE + HW at 20 DAS. Significantly the maximum weed control efficiency and lowest weed index was recorded under weed free followed by pendimethalin at 580 g/ha as PE *fb* one hand weeding at 20 DAS. All the growth parameter of green gram *viz.* plant height, number of branches and total dry matter accumulation/plant were significantly higher in weed free. The next best and among the different weed management treatments, application of pendimethalin at 580 g/ha as PE *fb* one hand weeding at 20 DAS treatment produced higher growth attributes than other method of weed control. But it was at par with imazethapyr 75 g/ha as PE + HW at 20 DAS. The significant effect on growth character of plant was noticed due to different integrated weed management treatments which resulted in enhanced yield contributing character, seed and straw yield. Among the different weed management treatments, application of herbicide, pendimethalin at 580 g/ha as PE *fb* by one hand weeding at 20 DAS resulted significantly higher seed and straw yield (1.17 and 2.08 t/ha, respectively) than rest of weed control treatment. The gross and net monetary returns were found maximum (` 66053 and 42092/ha, respectively) in weed free treatment followed by application of pendimethalin at 580 g/ha as PE + HW at 20 DAS (` 61601 and 40281/ha, respectively). Benefit cost ratio was maximum in pendimethalin at 580 g/ha as PE + HW at 20 DAS (2.89) followed by weed free (2.76). However, the gross and net monetary returns were maximum under weed free check but lowest B-C ratio as compared to integrated weed management treatment due to higher cost of manual labour for weeding.

Weed management in rainfed pigeonpea

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The present investigation was carried out at Post Graduate Research Farm, Agronomy section, College of Agriculture, Dhule, during the *Kharif* season of year 2016. Experiment consisted of ten treatments laid out in randomized block design with three replications. The treatment included, weed free, weedy check, pendimethalin 1.0 kg/ha as PE *fb* HW at 40 DAS, pendimethalin 1.0 kg/ha as PE *fb* HW at 20 and 40 DAS, imazethapyr 35 EC + imazamox 35 EC 0.075 kg/ha at 20 DAS *fb* HW at 40 DAS, quizalofop ethyl 100 g/ha (20 DAS) *fb* HW at 40 DAS, pendimethalin 1.0 kg/ha (3 DAS) + quizalofop-ethyl 100 g/ha (20 DAS) *fb* HW at 40 DAS, pendimethalin 1.0 kg/ha (3 DAS) + quizalofop-ethyl 100 g/ha (20 DAS), pendimethalin 1.0 kg/ha as PE + imazethapyr 35 EC + imazamox 35 EC 0.075 kg/ha (20 DAS) *fb* HW at 40 DAS and pendimethalin 1.0 kg/ha as PE + imazethapyr 35 EC + imazamox 35 EC 0.075 kg/ha (20 DAS). Among integrated weed management treatments, sequential application of pendimethalin at 1.0 kg/ha as PE + imazethapyr 35 EC + imazamox 35 EC 0.075 kg/ha (20 DAS) *fb* HW at 40 DAS exhibited maximum weed control efficiency and lowest weed index. All the growth parameter of pigeonpea *viz*. plant height, number of branches and total dry matter accumulation/ plant were significantly higher in the aforesiad integrated weed management treatment, a than other method of weed control. But it was at par with pendimethalin 1.0 kg/ha as PE *fb* HW at 20 and 40 DAS. The significant effect on growth character of plant was noticed due to different integrated weed management treatments which resulted in enhanced yield contributing character of pigeonpea. Among the integrated weed management treatments, application of pendimethalin 1.0 kg/ha as PE + imazethapyr 35 EC + imazamox 35 EC 0.075 kg/ha (20 DAS) *fb* HW at 40 DAS produced significantly higher grain and stover yield of pigeonpea (2215 and 5610 kg/ha, respectively) than other method of weed control and it was found at par with application of pendimethalin 1.0 kg/ha as PE *fb* HW at 20 and 40 DAS (2173 kg/ha and 5560 kg/ha, respectively). The same trend in case of nutrient uptake by plant was observed. However, the gross and net monetary returns were the maximum under weed free treatment but lowest B-C ratio as compared to sequential application of pendimethalin 1.0 kg/ ha as PE + imazethapyr 35 EC + imazamox 35 EC 0.075 kg/ha (20 DAS) *fb* HW at 40 DAS and pendimethalin 1.0 kg/ha as PE *fb* HW at 20 and 40 DAS due to higher cost of manual labour for weeding.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Productivity of *Bt* cotton and weed control efficiency as influenced by moisture conservation practices under drip irrigation

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Cotton (*Gossypium hirsutum* L.) is a very important commercial fibre and cash crop of India, it sustains the cotton textile industry which is perhaps the largest segment of organized industries in the country. The economy of agricultural community in Vidarbha region of Maharashtra is mostly dependent on the cotton. Plastic mulch helps prevent soil water loss during dry years and sheds excessive water away from the crop root zone during periods of excessive rain fall. This can reduce irrigation frequency and amount of water; it may help reduce the incidence of moisture related physiological disorders.

A field investigation was conducted at Cotton Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the *Kharif* season of 2016-2017. The experiment was laid out in RBD with seven treatments and three replications in order to study the effect of different moisture conservation practices on growth, seed cotton yield and water use; and weed control efficiency under drip irrigated *Bt* cotton. The treatments comprises of poly mulch of silver top of 30 micron laid on ridges and furrow with drip, bio mulch of sunhemp between two rows of cotton at 40 days after sowing on broad bed and furrow (BBF) with drip, poly mulch on broad bed and furrow, dust mulch on flat bed, no mulch on flat bed with drip, conventional irrigation on ridges and furrow, farmers practice. Plant height, boll numbers per plant, boll weight were significantly maximum with bio-mulching with sunhemp between two rows of cotton followed by poly-mulching on broad bed furrows (BBF) with drip. This indicated moisture conservation practice of bio-mulching on BBF with drip recorded highest seed cotton yield (3.70 t/ha) followed by poly mulching on BBF (3.45 t/ha) over no irrigation (rainfed condition). It indicates increased seed cotton yield by 64.4% under bio-mulch and 53.1 under poly mulch on BBF than rainfed on ridges and furrows. Similarly, water use efficiency was higher with these treatments. Bio-mulching of sunhemp increased moisture availability and addition of nutrients through sunhemp dry matter decomposition during crop growth and yield of *Bt* cotton. In relation to weed dry matter indicated that weed dry matter was lowest (374 kg/ha) in poly mulch on BBF with drip and highest weed dry matter (1106 kg/ha) was recorded with conventional irrigation. Similarly, weed control efficiency was highest (66%) with poly mulch on BBF with drip. Highest bacterial population 82×10^6 CFU g^{-1} soil was with bio-mulching and poly mulch on BBF. Moisture conservation practice of bio-mulch on BBF with drip recorded highest (2.33 in 30 cm^{-3} soil) number of earthworms, followed by poly mulch on BBF with drip and poly mulch on RF with dripwith the values of 1.67 and 1.00 respectively.

Significantly, highest seed cotton yield of *Bt* cotton with better water use and weed control efficiency was found with bio-mulching of sunhemp between two rows of cotton at 40 DAS followed by poly-mulching on broad bed furrows (BBF) with drip irrigation.

Integrated weed management in pre-seasonal (autumn) sugarcane

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A field experiment was conducted on medium deep black soil at Central Sugarcane Research Station, Padegaon during 2016-17 to evaluate the effective method of weed management in sugarcane. The experiment was laid out in randomized block design replicated thrice with 10 treatments *viz.* T_1-weedy control, T_2: weed free check, T_3: two weeding, at 30 and 60 DAP + 1 hoeing at 90 DAP, T_4: metribuzin 1.0 kg/ha as PE + 2, 4-D at 1.0 kg/ha POE at 60 DAP, hoeing at 90 DAP, T_5: metribuzin 0.5 kg/ha + 2, 4-D 0.5 kg/ha POE at 25 DAP, hoeing at 60 and 90 DAP, T_6: metribuzin 0.75 kg/ha + 2, 4-D 0.75 kg/ha POE at 25 DAP, hoeing at 60 and 90 DAP, T_7: metribuzin at 1.0 kg/ha + 2,4-D at 1.0 kg/ha POE at 25 DAP, hoeing at 60 and 90 DAP, T_8: metribuzin at 1.0 kg/ha + 2, 4-D at 0.5 kg/ha POE at 25 DAP, hoeing at 60 and 90 DAP, T_9: metribuzin at 0.5 kg/ha + 2, 4-D at 1.0 kg/ha POE at 25 DAP, hoeing at 60 and 90 DAP, $T_{10:}$ atrazine at 2.0 kg/ha + 2, 4-D at 0.5 kg/ha POE at 25 DAP, hoeing at 60 and 90 DAP. Metribuzin + 2, 4-D were applied as a tank mixin T_5, T_6, T_7, T_8, T_9 and T_{10} treatments. All the weed management practices caused significant reduction in weed density over weedy check. At 60 DAA, weed free check recorded highest weed control efficiency (82.1%) followed by two weeding at 30 and 60 DAP + 1 hoeing at 90 DAP (75.2%) and metribuzin at 1.0 kg/ha + 2,4-D at 1.0 kg/ha POE at 25 DAP, hoeing at 60 and 90 DAP (66.9%). At 90 DAA application of metribuzin 0.5 kg/ha + 2, 4-D at 1.0 kg/ha POE at 25 DAP, hoeing at 60 and 90 DAP recorded highest weed control efficiency (99.1%) followed by metribuzin at 1.0 kg/ha + 2, 4-D at 1.0 kg/ha POE at 25 DAP, hoeing at 60 and 90 DAP (99.0%) and weed free check (98.0%). While weedy free check (T_2) recorded significantly the highest cane yield and CCS yield (161.7 t/ha, 21.8 t/ha) which was found at par with application of metribuzin at 0.5 kg/ha + 2, 4-D at 1.0 kg/ha POE at 25 DAP, hoeing at 60 and 90 DAP (160.3 t/ha, 21.6 t/ha), metribuzin at 1.0 kg/ha as PE, 2, 4-D at 1.0 kg/ha POE at 60 DAP, hoeing at 90 DAP (156.3 t/ha, 21.1 t/ha), metribuzin at 1.0 kg/ha + 2, 4-D at 0.5 kg/ha POE at 25 DAP, hoeing at 60 and 90 DAP (154.5 t/ha, 20.5 t/ha) and two weeding at 30 and 60 DAP + 1 hoeing at 90 DAP (153.3 t/ha, 20.7 t/ha).

Performance of herbicide on weed dynamics, growth, yield and economics of *suru* sugarcane

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A field experiment was conducted to assess the management of weeds in spring sugarcane *var*. CoM-0265 during 2010-11 at Central Sugarcane Research Station, Padegaon. Ten treatments consisting of weedy check, hoeing at 30, 60 and 90 DAP, atrazine 2 kg/ha (PE) *fb* 2, 4-D (1 kg/ha) at 60 DAP, atrazine at 2 kg/ha after 1st irrigation (PE) and hoeing followed by 2, 4-D at 1 kg/ha at 75 DAP , metribuzin at 1.25 kg/ha (PE) followed by 2, 4-D at 1 kg/ha at 75 DAP, atrazine at 2 kg/ha (PE) + almix 20 g/ha at 75 DAP, metribuzin at 1.25 kg/ha (PE) + almix 20 g/ha at 75 DAP, atrazine at 2 kg/ha (PE) + ethoxysulfuron 50 g/ha at 75 DAP, atrazine at 2 kg/ha (PE) + Dicamba 350g/ha at 75 DAP and metribuzin at 1.25 kg/ha (PE) + Dicamba 350g/ha at 75 DAP replicated thrice in randomized block design. At 30 and 60 days after planting (DAP), the minimum weed flora (16/m^2 and 19/m^2) and biomass (09 g/m^2 and 09 g/m^2) were observed in the treatment atrazine at 2 kg/ha after 1st irrigation (PE) and hoeing followed by 2, 4-D at 1 kg/ha at 75 DAP. In regard to weed control efficiency (WCE), it was also observed highest in same treatments (84.21% and 85.25%) followed by atrazine at 2 kg/ha (PE) + Almix 20 g/ha at 75 DAP (79.66% and 71.18%). At 90 and 120 DAP the minimum weed flora (31/m^2 and 29/m^2) and biomass (22 g/m^2 and 21 g/m$^{2)}$ were observed in the atrazine 2 kg/ha after 1st irrigation (PE) and hoeing followed by 2, 4-D at 1 kg/ha at 75 DAP. Atrazine 2 kg/ha after 1st irrigation (PE) and hoeing followed by 2, 4-D 1 kg/ha at 75 DAP produced significantly higher cane and CCS yields (125.3 and 17.2 t/ha, respectively), gross monetary returns (` 229212/ha) and maximum weed control efficiency (72.33%).

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Pre- and post-emergence herbicides for weed management in *suru* sugarcane

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Comparative efficacy of imazapic 24% SL against weed control was studied during 2010-11 at Central Sugarcane Research Station, Padegaon, Maharashtra. The experiment was laid out in randomized block design with 13 treatments in 3 replications. Treatment consists of three doses of imazapic 24% SL as pre-emergence (72,96 and 120 g/ha) and five doses as post-emergence (72, 96, 120, 240 and 480 g/ha), pre-emergence atrazine 50% WP (1000 g/ha) and metribuzin 70% WP (2000 g/ha), IWM of metribuzin 1.0 kg/ha as pre-emergence + post-emergence 2,4-D 1.0 kg/ha + hoeing at 90 DAP, weed free (weeding at 30, 60, 90 and 120 DAP) and unweeded control were tried.

Experimental field was infested with monocot weed, *viz. Cyperus rotundus, Cynadon dactylon, Panicum isachami, Commelina benghalensis, Brachiaria* spp. and dicot weed, *viz. Parthenium hysterophorus, Portulaca olerecea, Amaranthus viridis, Digeria arvensis, Ipomea aquitica* and *Euphorbia* spp. All the herbicidal treatments significantly reduced the weed density and weed dry weight over unweeded control. Significantly lower weed dry weight was recorded with hand weeding (23, 6 and 4 g/m^2 at 20, 40 and 60 days stages, respectively). Among the herbicides PE application of metribuzin 70% WP at 2000 g/ha recorded significantly lesser weed dry weight (7, 17 and 27 g/m^2 at 20, 40 and 60 days stages, respectively) and weed density (11, 16 and 21/m^2 at 20, 40 and 60 days stages, respectively) than other herbicides. Among the imazapic 24% SL treatments, EPOE application at 480 g/ha recorded significantly higher weed control efficiency (62.1, 60.0 and 55.1%, respectively) at 20, 40 and 60 DAS, as compared to rest of the treatments of herbicides except pre-emergence application of metribuzin 70% WP 2000 g/ha where it was at par.

Sugarcane yield was significantly higher in weed free treatment (110.8 t/ha) as compared to rest of treatments, except integrated weed management treatment of PE application of metribuzin 1.0 kg/ha + POE application of 2,4-D 1.0 kg/ha + hoeing at 90 DAP (106.98 t/ha) where it was at par. Among the herbicidal treatments application of metribuzin 70% WP (2000 g/ha) recorded higher cane yield (93.49 t/ ha) than treatments of various doses of imazapic 24% SL except dose of PE application of imazapic 24% SL at 480 g/ha (87.5 t/ha) where it was at par. The sugarcane crop had not shown any phytotoxic effect such as chlorosis, necrosis, wilting, scorching, hyponasty and epinasty. Thus for effective weed management in *suru* sugarcane early post-emergence application of imazapic 24% SL at the rate 480 g/ha may be adopted as an alternative means to metribuzin for weed control in sugarcane.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Weed management in *Bt* cotton

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Cotton plays an important role in textile industries and livelihood for millions of farmers, those concerned with its trade, processing, manufacturing and other allied sectors. It is mainly used in the manufacturing of cloth for mankind to all over the world. Improper time of sowing and weed management practices significantly influences the weed growth and cotton development at initial stages and it leads to reduce yield up to 60-80 per cent. Cotton is cultivated under wider plant spacing and heavily fertilized, which in turn invite multiple weed species infestation. Weeds compete with the crop for the nutrient, moisture, space and light, thus, affecting the growth and development of cotton during early stages of growth. Reduction in yield due to weeds in cotton to the extent of 50 to 85%. Therefore, it is very essential to keep the field weed free for about 50 to 60 days after sowing to get optimum yield. Conclusively, timely weed control plays an important role in success or failure of cotton cultivation.

Herbicides are capable of giving the crop a relatively better weed free situation in the early stage of crop. Pre-emergence herbicides like pendimethalin can control the weeds in early stage and thereby ensure efficient utilization of inputs applied by the farmers. The weeds which appear in the later period of crop growth could be controlled by post-emergence herbicides like quizalofop-ethyl or pyrithiobac sodium. Thus, proper herbicides application could solve the weed problem and prove efficient and economical. Hence, field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore during winter seasons of 2015-16 and 2016-17. The experimental field is situated in Western Agro climatic zone of Tamil Nadu and located with 11°N latitude and 77° E longitude at an altitude of 426.7 m above mean sea level and the farm receives the normal total annual rainfall of 674.2 mm in 45.8 rainy days. Fields with uniform weed flora were selected for the experiment. Results revealed that, early sowing of *Bt* cotton hybrid on 1st August in combination with sequential application of pendimethalin 38.7% CS as pre-emergence at 0.68 kg/ha followed by pyrithiobac-sodium as post–emergence at 62.5 g/ha enhanced productivity and profitability of *Bt* cotton.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Integrated weed management in niger

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The field investigation entitled 'Integrated weed management in Niger (*Guizotia abyssinica* L. cass)' was carried out during *Kharif* 2016 at Department of Agronomy, College of Agriculture, Latur, Maharashtra with objectives to study the effect of different weed control method on growth and yield of Niger with find efficency of weed control and study of economics of diffrent treatmnets. The soil was clayey in texture, low in available nitrogen (240.6 kg/ha), medium in available phosphorus (21.81 kg/ha), very high in available potassium (619 kg/ha) and slightly alkaline in reaction with pH 8.3. The experiment was laid out in randomized block design with three replications and variety *PNS-6* as a test crop along with nine treatments, *viz.* T1 **-** pendimethalin at rate 0.75 kg/ha as pre-emergence spray, T_2- pendimethalin at rate 0.75 kg/ha as pre-emergence spray + one hoeing at 25 DAS, T_3- pendimethalin at rate 0.75 kg/ha as pre-emergence spray + one hoeing at 25 DAS + one hand weeding at 40 DAS, T_4- quazilfop-ethyl 5% EC at rate 37.5 g/ha at 15–20 DAS + one hoeing at 25-30 DAS, T_5 - propquizofop 10% EC at rate 62 g/ha at 15–20 DAS + one hoeing at 25–30 DAS, T_6- fenoxoprop-ethyl 9.3% EC at rate 37.5 g/ha at 15–20 DAS + one hoeing at 25–30 DAS, T_7- farmer's practice (one hoeing at 30 DAS + one hand weeding at 40 DAS), T_8- weed free (three hand weeding's at 15, 30 and 40 DAS) and T_9 - weedy check. The gross and net plot size of each experimental unit was 5.4 x 4.2 m and 4.5 x 3.6 m, respectively. Sowing was done on 29th June, 2016 by dibbling method. The recommended cultural practices and plant protection measures were taken. Among different chemical weedicides the application of quazilfop ethyl 5% EC at rate 37.5 g/ha at 15-20 DAS + one hoeing at 25-30 DAS (T_4) recorded significantly higher growth, yield contributing characters and yield of niger.

Growth and yield parameters such as highest mean plant height per plant (125.07 cm), branches per plant (11.27), heads per plant (34.93), dry matter g/plant (17.81) and yield 0.583 t/ha was found with T_4 (quazilfop-ethyl 5% EC at rate 37.5 g/ha at 15-20 DAS + one hoeing at 25-30 DAS). As well as low weed dry matter weight/m^2 (7.89), weed index (10.46%) and highest weed control efficiency (70.26%) was noted with the same treatment.

Low cost and ecofriendly weed management technologies for jute

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Fourty per cent of the jute's total cost of cultivation goes in weeding process alone. Experiments were conducted at ICAR-CRIJAF, to screen new generation herbicides, smother crops and use modified CRIJAF nail weeder and CRIJAF herbicide applicator in jute for its economic and ecofriendly weed management. Pre-emergence herbicide, ipfencarbazone 22.8% ($C_{18}H_{14}Cl_2F_2N_4O_{2,}$ 1-aryl-4-carbamoyl-1,2,4-triazolinone) at 68.43 g to 91.24 g/ha, showed no phyto toxicity on jute (irrigated and rain fed) and recorded fibre yield from 3.3-4.0 t/ha (3.3 t/ha, in two manual weedings). Grass weed control by ipfencarbazone 22.8% at 68.43 g and 91.24 g/ha were 87% and 90% with respect to control. Broad-leaf and sedge control by ipfencarbazone 22.8% at 68.43 g and 91.24 g/ha were 52% and 40% over two manual weedings, respectively. It showed no phyto toxicity on rice in sequence (3.1-3.5 t/ha) and *Rabi* crops (mustard, lentil, pea, *etc*.) or cucurbits grown on gunny bag based soil columns in rice field. Pretilachlor 50 EC at 0.9 kg/ha applied 48 hours after sowing with irrigation effectively controlled grasses and some broad-leaved weeds in jute-green gram intercrop, mixed crop and relay crops. Green gram (*Vigna radiata*) reduced more than 90% sunlight entry in soil and reduced weed biomass by 76% at 25 DAS. Green gram yield ('*TMB-37*', 52-55 Days) in intercrop, mixed crop and relay crops were 900 kg, 700 kg and 620 kg/ha, respectively with fibre yields of 3.05 t, 3.06 t and 2.4 t/ha, respectively. Small grain cv. '*Sukumar*' (65 days) yielded 700 kg pulse/ha with 3.1 t jute fibre/ha. Jute fibre equivalent of intercropping system was 4.4 to 4.7 t/ha with B:C ratio of 1.80. In mixed crop, 30 jute and 6 green gram seedlings were maintained/m^2 and excess jute seedlings around 20 cm dia. of green gram were removed within 15 DAS. Low jute population in intercropping, (0.26 million/ha, closing alternate holes in modified CRIJAF MRS) and green gram (0.25 million/ha, yielded 2.75 t jute fibre and 680 kg pulse grain/ha), eliminated 2^{nd} weeding (25 man days/ha), thinning operation (22 man days/ha), reduced jute harvest and bundling time (14 man days/ha) and fibre extraction time (single plant extraction) by 37 man days/ha. *i.e.* total 98 (25 + 22 + 14 + 37) man days/ha and reduced expenditure by ` 24500/ha (Rs. 250/man days). Sole jute (0.45 to 0.55 million/ha) requires 210 man days/ha for its thinning, 2^{nd} weeding, harvesting, bundling and its single plant extraction process. Experiments at ICAR-CRIJAF (2007-2009) showed 0.26 million jute plant/ha produced 2.95 tons fibre/ha with average plant and fibre weight of 197 g and 11.39 g, respectively. More than 95% of composite weeds were controlled by CRIJAF nail weeder (5 nails in series, nail dia. 6-8 mm) and its assemblies (fibre yield 3.94 t/ha and saved 70 man days/ha). CRIJAF herbicide applicator (glyphosate 2.43 kg SL/ha) was economical for jute and other field crops and saved 60 man days/ha.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Bio-efficacy of diuron along with sequential application of herbicides for weed control in cotton

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A field experiment was conducted in red and black soils at Professor Jayashankar Telangana State Agricultural University, Rajendranagar during *Kharif* 2017 to study the bioefficacy of diuron with sequential application of herbicides for weed control in cotton. The treatments consisted, diuron 80% WP at 0.5 kg/ha, 0.75 kg/ha and 1.0 kg/ha and pendimethalin 38.7% CS at 677 g/ha *fb* pyrithiobac sodium + quizalofop p ethyl, intercropping with sunhemp, polymulch, mechanical weeding thrice at 20, 40, 60 DAS and unweeded control. The experiment was laid out in randomised block design replicated thrice. The weed flora in experimental field was dominated by *Cynodon dactylon, Rottboellia exaltata* and *Dactyloctenium aegyptium, Cyperus rotundus, Parthenium hysterophorus, Trianthema portulacastrum* and *Commelina benghalensis* in red soil. In black soil, predominant flora was *Cynodon dactylon, Cyperus rotundus, Parthenium hysterophorus, Euphorbia geniculata, Tridax procumbens, Cyanotis cristata, Digera arvensis* and *Celosia argentea*. Mechanical weeding thrice at 20, 40 and 60 DAS, polymulch registered excellent weed control in both red and black soils. Among the herbicides, diuron at 1.0 kg/ha PE in red soil and diuron at 1.0 kg/ha and 0.75 kg/ha PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE in black soil reduced the weed density and weed dry matter. Greater WCE was recorded with mechanical weeding and was closely followed by polymulch and diuron at 1.0 kg/ha PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE in both red and black soil. In black soils even diuron at 0.75 kg/ha PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE also registered higher WCE. Visual phytotoxicity was observed with diuron at 1.0 kg/ha PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE in black soil only. Plant population was reduced significantly with diuron at 1.0 kg/ha PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE in black soil. Mechanical weeding thrice at 20, 40 and 60 DAS, polymulch, diuron at 1.0 kg/ha and 0.75 kg/ha PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE enhanced the growth parameters. The yield and yield attributes were higher in case of polymulch and mechanical thrice at 20, 40 and 60 DAS. Among the herbicides, diuron 1.0 kg/ha PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE in red soil and diuron 0.75 kg/ha PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE in black soil registered higher kapas and stalk yields. Considering the economic indices, higher net and gross returns were realized with polymulch, mechanical weeding thrice and among the herbicides, diuron 1.0 kg/ha PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE in red soils and diuron 0.75 kg/ha PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE in black soil recorded higher returns. However the B: C ratio was significantly highest with diuron 1.0 kg/ha PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE in red soils and diuron 0.75 kg/ha PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE in black soil.

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Weed management practices in spring planted sugarcane + summer crop intercropping system under south Saurashtra region of Gujarat

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The field experiment was carried out at Main Sugarcane Research Station, Junagadh Agricultural University, Kodinar, Gujarat, India during 2013-14 to 2015-16 to find out the effective weed management practices in sugarcane + summer crop intercropping system. The soil of experimental site was clayey in texture with pH 7.96, EC 0.58 dS/m, organic carbon 0.67%, available P_2O_5 33.28 kg/ha and K_2O 406.00 kg/ha.

The trial was laid out in split plot design with three replications. The treatment consisted of five cropping system {Sole sugarcane, sugarcane + green gram (*Vigna radiata* L. Wilczek), sugarcane + black gram (*Vigna mungo* L. Hepper), sugarcane + sesame (*Sesamum indicum* L.) in 1:1 row ratios and sugarcane + groundnut (*Arachis hypogaea* L.) in 1:2 row ratio} in main plots and three weed control treatments (Un weeded control, hand weeding at 20 and 40 DAS of intercrop and pendimethalin 30 EC 0.90 kg/ha as PE + one hand weeding at 30 DAS of intercrop) in sub plots. Sugarcane variety *'CoN 91132'* was planted at 90 cm row spacing during first week of February each year for conducting this experiment. The seeds of intercrop variety of green gram- '*GM 4'*, black gram- '*Guj.urd 1'*, groundnut- '*GJG 31'* and sesame- '*Guj. til 2'* were sown under this experiment.

The perusal of three years data indicated that weed control treatments significantly influenced the cane yield during the individual year as well as in pooled analysis. Weed control with two manual hand weeding at 20 and 40 days after sowing (DAS) of intercrop gave significantly higher cane yield (115.60 t/ha) over control (61.41 t/ha) and remained at par with pre-emergence application of pendimethalin 30 EC 0.90 kg/ha + 1 hand weeding at 30 DAS of inter crop (115.10 t/ha). Similar results were obtained in cane equivalent yield and number of millable canes. Uncontrolled weeds significantly reduced the growth parameters like millable cane height and single cane weight compared to weed control treatments. The weed control treatments significantly reduced the total number of weeds as well as weed dry matter as compared to un weeded control. The highest weed control efficiency was recorded with two hand weeding (75.26%) followed by pendimethalin + one hand weeding (73.96%).

The qualitative characteristics of sugarcane juice *viz.* brix, sucrose, commercial cane sugar and extraction per cent were greatly influenced by the weed controlling measures except purity percentage, which was not differed significantly among the treatments. The weed control with two hand weeding and application of pendimethalin + one hand weeding fetched benefit: cost ratio of 2.35 and 2.36, respectively.

Assessment of growth and yield of barley in relation to nutrient and weed management

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India accounts for 7.68% of total global agriculture output and contribution of agriculture sector in Indian economy is much higher than world's average 6.1% and has second place in contribution to the total GDP (16.9%) in 2017. Among diversified crops, Barley *(Hordium vulgare* L.*)* is one of the most important and oldest cereal crop having importance as food and as well as feed. It ranks fourth with respect to area and production after wheat, rice and maize. Barley is a nutritious cereal with 8-10% protein, 69.6% carbohydrate, 1.3% fat, 3.9% crude fiber, 1.5% ash, 26 mg calcium, 215 mg phosphorus and 1.2% minerals The area, production and productivity of barley in World 2500 kg/ha, U.P. and Rajasthan, major producing states, occupy 64% of the total area and 72% of the total production of barley in India. The area, production and productivity of barley in India is 2.02 t/ha, respectively. Similarly, the area, production and productivity of Uttar Pradesh is 2.12 t/ha, respectively (Source FAI 2015-16). Weed problem is one of the major barriers responsible for low productivity of barley because, weed competes with the crop for moisture, nutrients, space, light *etc*. The weed in India are causing substantial losses to agriculture production and the annual losses in terms of money come to the ` 1650 crores (Joshi 2002). Weeds constitute one of the biggest problems in agriculture that not only reduce the yield and quality of barley crop but also utilize essential nutrients (Malik *et al.* 1989) Plant nutrition plays an important role in growth and productivity of a crop.

Nitrogen fertilization always result in an increase in above ground dry matter and root biomass production which result in to higher productivity as well as higher residues left in the soil after the harvest of the crop which helps in improving the fertility of the soil. Farmyard manure (FYM) and vermicompost is being used as a major source of organic manure in field crops. Therefore now it becomes inevitable to work out on possible best suitable combination of FYM, vermicompost and chemical fertilizer in order to get sustainable production of barley (Tripathi *et al.* 2010).

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Integrated weed management in pearl millet

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Pearl millet (*Pennisetum glaucum* L.) is a staple food grain crop of the arid and semi-arid regions of India. It is one of the important cereal crops globally after rice, wheat and maize. Weeds deplete 30-40% of applied nutrients from soil and compete with the crop plants for soil, moisture and sunlight too. Under scarcity of human labour, use of herbicide is the best option to reduce the weed menace during early stages of crop growth. However, neither herbicides nor mechanical cultivation are adequate for consistent and acceptable weed control. Therefore, use of chemical along with manual weeding is best option for effective weed management. Keeping this in view, an attempt was made to find out the effect of integrated weed management on weed dynamics, crop productivity, nutrient removal and economics of rainy season pearl millet.

A field experiment was conducted during the *Kharif* season of 2013 to 2015 at pearl millet Research Station, Jamnagar, Gujarat to study the pre- and post-emergence atrazine effect with manual weeding on weed dynamics, crop productivity, nutrient removal and economics of pearl millet (*Pennisetum glaucum* L.). The experiment was laid out in a randomized block design comprising of eight weed control treatments with three replications. The experimental field was infested with grassy weeds like, *Cynondon dactylon*, *Echinochloa colona*, *E. crusgali*; broad-leaf weeds like, *Convolvulus arvensis*, *Digera arvensis*, *Commelina benghalensis*, *Amaranthus viridis*, *Trianthema portulacastru*, *Eclipta alba* and Sedges like, *Cyperus rotundus*, *C. esculentus* during all the years of experimentation.

The results revealed that lesser weed density (8.22/m^2 at 30 DAS and 11.89/m^2 at harvest) and weed-biomass (20.2 g/m^2), higher weed control efficiency (84.28%) and lower weed index (7.79%) were observed under post-emergence application of atrazine 0.4 kg/ha + hand weeding (HW) at 35 days after sowing (DAS). Higher growth and yield attributes, grain (3.28 t/ha) and stover (5.10 t/ha) yields and lower N (2.99 kg/ha), P (0.46 kg/ha) and K (2.76 kg/ha) removal by weeds were found with the pre-emergence application of atrazine 0.5 kg/ha + HW at 35 DAS, which remained at par with post-emergence application of atrazine 0.4 kg/ha + HW at 35 DAS. The maximum net returns (` 40,087/ha) and benefit: cost ratio (2.97) was acquired with same treatment and remained comparable with post-emergence application of atrazine 0.4 kg/ha + HW at 35 DAS (` 38,780/ha and 2.90 respectively).

Thus, in case of labour scarcity pre-emergence application of atrazine 0.5 kg/ha followed by hand weeding at 35 DAS or post-emergence application of atrazine 0.4 kg/ha at 3 leaf stage of weed followed by hand weeding at 35 DAS could be a best option for achieving higher yield, net returns, benefit: cost ratio as well as significant weed suppression in pearl millet.

Efficacy of weed management practices in sugarcane and their effect on cane productivity

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Sugarcane is an important cash crop covering more than sixty five thousand hectare area in Narsinghpur district. Sugarcane has third position in area and second in revenue generation after chickpea to the district farmers. More than ten promising and released varieties from JNKVV, Jabalpur; UPCSR, Shahjahanpur: IISR, Lucknow: SBI, Coimbatore and VSI, Maharashtra planted in the district. Sugarcane suffered with biotic and abiotic factors such as pathogens, hailstorms and weeds. An extensive survey was conducted during 2016-17 in six blocks of the Narsinghpur district and found that the weeds play a major role in reducing the sugarcane growth and yield upto the tune of 22% followed by insect pest and disease 10-12%.

Main weeds of sugarcane in the district are Motha, striga, cans, dudhi, akari, gajarghas, sawa, kanni, wild jai *etc.* Among these striga cause severe damage to the cane crop. Mostly striga found in the field near to cane roots when rainy season start and acts as root parasite. Farmer generally used alone 2, 4-D for their control. But it is not completely manage the problem.

A field experiment was conducted at farmer's field under frontline demonstration during spring season 2017-2018 in double row planting method (0.7+5 meter distance) with Co JN 86600 variety of sugarcane. A set of weedicide alone and in combination between them. Weedicide + manual weed control method are used in the present investigation. The major weedicide which we have taken in the experiment are 2, 4-D, metribuzin, glysophate and atrazine at their recommended dose. The result revealed that the pre-emergence application of metribuzin at 1.5 kg/ha followed by hoeing through tractor after 120 days of planting not only gave the good control of both narrow and broad-leaf weeds but also increased the number of tillers, millable canes and yield (98.1 t/ha) than pre hoeing + application of 2, 4-D after 120 days (83.5 t/ha). Highest net return and benefit cost ratio was found with application of metribuzin and hoeing. In those plots where applied only pre emergence of pendimethalin was at par in yield with only hoeing. Pre emergence glysophate at the rate of 1.5. It manage all the weeds upto 50 days but after 50 days 2, 4-D treatment in the same plot gave significant result in managing the weeds. Initial hoeing + 2, 4-D and earthing was at par with the applicated plot of 2, 4-D + hoeing.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Effect of fertigation levels and weed management practices on productivity of *Bt* cotton

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A field investigation "Effect of fertigation levels and weed management practices on productivity of *Bt* Cotton" was conducted at AICRP on Weed Management farm, Deparment of Agronomy, Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *Kharif* season 2017. The experiment was laid out in Split plot design with three replications. The main plot treatments comprised of different levels of fertilizer in five splits at 75%, 100% and 125% RDNK/ha of fertilizers given through fertigation, however P was applied as basal dose and these treatment were compared with 100% soil application of fertilizers. Whereas, sub plot treatments comprised of five weed management practices, *viz.* pendimethalin 1 kg/ha PE *fb* pyrithiobac sodium 0.062 kg/ha + propaquizafop 0.075 kg/ha 25-30 DAS + 1 hand weeding at 45-50 DAS, pendimethalin 1 kg/ha PE *fb* paraquat 0.6 kg/ha at 40-50 DAS, directed spray of paraquat 0.3 kg/ha at 30 DAS *fb* 1 HW 15 Days after spraying and paraquat 0.6 kg/ha 60 DAS *fb* 1 HW 15 Days after spraying, farmer practices –3 hoeing 15-20 days interval after sowing *fb* 3 HW and weedy check. The major weed flora *viz; Cyperus rotundus, Cynodon dactylon, Commelina benghalensis, Digera arvensis, Parthenium hysterophorus, Celosia argentea, Ipomea* sp.*, Sorghum halpenses, Euphorbia hirta, Alternanathera sessile* and *Phyllanthus niruri* were found during study.

Results revealed that, in cotton all the growth parameters *viz.* plant height, dry matter accumulation per plant, sympodial branches and yield attributes *viz.* bolls picked and seed cotton yield were substantially enhanced by drip fertigation level at 125% RDNK/ha than lower fertigation levels 75%, 100% and over conventional soil application with 100% RDNK/ha. As a consequence of better growth and yield attributes, drip fertigation at 125% RDNK/ha had recorded higher seed cotton yield of 2.64 t/ha. The GMR (` 130651/ha), NMR (` 69774/ha) and B: C (2.09) were also found maximum with drip fertigation at 125% RDNK/ha.

Among the herbicidal treatments, directed spray of paraquat 0.3 kg/ha at 30 DAS *fb* 1 HW 15 days after spraying and paraquat 0.6 kg/ha at 60 DAS *fb* 1 HW 15 days after spraying recorded significant reduction in weed density, weed dry matter, highest weed control efficiency and lowest weed index. Which ultimate resulted in maximum seed cotton yield. The maximum gross monetary return (` 133011/ha) was recorded with farmers practice -3 hoeing 15-20 days interval after sowing *fb* 3 HW and maximum NMR (` 69189/ha) and B: C ratio (2.22) was recorded in directed spray of paraquat 0.3 kg/ha at 30 DAS *fb* 1 HW 15 days after spraying and paraquat 0.6 kg/ha at 60 DAS *fb* 1 HW 15 days after spraying. Lowest GMR, NMR and B: C ratio was found in weedy check.

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Evaluation of post-emergence herbicides on weed characters, yield and economics of *Bt* cotton

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Cotton is the most important fibre and commercial crop of India and Tamil Nadu state as well. It is very sensitive to crop weed competition due to slow growth during early stage and wider spacing. Moreover, due to increasing problem of labour availability for cotton cultivation, use of post-emergence herbicide along with hoeing has greater potential for effective weed management to combat the weeds emerged during later stages of crop growth.

In this context, two field experiments were conducted under irrigated condition during winter season of 2012–13 and 2013-14 at Cotton Research Station, Tamil Nadu Agricultural University, Srivilliputtur, Tamil Nadu state of India to evaluate the effectiveness of post-emergence herbicides in *Bt* cotton *Mallika*. A total of eight treatments were evaluated in a randomized block design (RBD) with three replications. The treatments consisted of pre-emergence application of pendimethalin (30.0% EC) at 1.0 kg/ha + 1 hoeing on 45 DAS**,** post-emergence application of quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing, pendimethalin at 1.0 kg/ha *fb* quizalofop-ethyl 50 g/ha + 1 hoeing on 45 DAS, post-emergence application of pyrithiobac-sodium 62.5 g/ha (30 DAS) + 1 hoeing on 45 DAS, combination of pyrithiobac-sodium 62.5 g/ha + quizalofop-ethyl 50 g/ha + 1 hoeing on 45 DAS, glyphosate 1.0 kg/ha (45 DAS) as directed spray and control plots of weed free check and un-weeded check.

The results revealed that application of pre-emergence herbicide pendimethalin at 1.0 kg/ha at 3 DAS followed by post-emergence herbicide (quizalofop-ethyl 50 g/ha at 30 DAS) + one hoeing or combined post-emergence application of pyrithiobac-sodium + quizalofop-ethyl + one hoeing on 45 DAS recorded lesser weed population and weed dry weight and higher weed control efficiency with lower weed index. These treatments were also comparable with pre-emergence application of pendimethalin + 1 hoeing. Higher yield attributes, *viz*, number of sympodia per plant, number of bolls per plant and boll weight were also registered by these treatments.

These three treatments also registered seed cotton yield of 2545, 2516 and 2497 kg/ha during 2012-13 and 2018, 2058 and 1972 kg/ha during 2013-14, respectively. The yield reduction due to weeds accounted 44.8 and 80.3 per cent during 2012-13 and 2013-14 respectively. The economic analysis indicated that higher total income, net income and Benefit:cost ratio were associated with pre-emergence application of pendimethalin *fb* post-emergence application of quizalofop-ethyl + one hoeing, combined post-emergence application of pyrithiobac-sodium + quizalofop-ethyl + one hoeing and pre-emergence application of pendimethalin + 1 hoeing in both the years of study.

It is concluded that pre-emergence application of pendimethalin 1.0 kg/ha + 1 hoeing was found to be a suitable and economical herbicidal weed management for winter irrigated cotton which was comparable with of pre-emergence application of pendimethalin at 1.0 kg/ha *fb* post-emergence herbicide quizalofop-ethyl 50 g/ha on 30 DAS + one hoeing or combined post-emergence application of pyrithiobac-sodium + quizalofop-ethyl + one hoeing.

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Weed management in cotton under conservation agriculture system

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A field investigation entitled "Weed management in cotton under conservation agriculture system" was conducted at research farm of AICRP Weed Management, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra) during 2016-17 on medium deep black soil. The experiment was laid out in split plot design with three replications. There were eighteen treatment combination consisting six tillage and crop management practices, 2 harrowings by tyne cultivator + 1 harrowing by blade harrow + residue, 2 harrowings by tyne cultivator + 1 harrowing by blade harrow, 1 harrowing by tyne cultivator + 1 roto till + residue, harrowing by tyne cultivator + 1 roto till, zero till + residue, zero till and three levels of weed management pendimethalin 38.7% CS 1 kg/ha. (PE) *fb*Pyrithiobac sodium 10% SL 0.062 kg/ha. (POE) 20 DAS, pyrithiobac sodium 10% SL0.062 kg/ha. (POE) 20 DAS *fb* 1 hand weeding 40 DAS, weedy check (unweeded). Cotton crop variety (Ajeet- 199) was sown on June 21, 2016 and three picking were done in Oct. Nov. and Dec. 2016.

The tillage treatment of 1 harrowing by tyne cultivator + 1 roto till + residue with weed management treatment *i.e.* Pyrithiobac sodium 10% SL 0.062 kg/ha. PoE 20 DAS *fb* one hand weeding at 40 DAS was found to be significantly minimum weed count, weed dry matter and higher weed control efficiency (%).

The values of plant growth, number of harvested bolls per plant, seed cotton yield per ha, biological yield and gross monetary returns of cotton were significantly increased with tillage treatment of one harrowing by tyne cultivator + one roto till + residue and weed management treatment of pyrithiobac sodium 10% SL 0.062 kg/ha. PoE 20 DAS *fb* 1 hand weeding 40 DAS as compared to other treatments. However, higher NMR and B:C ratio obtained in 2 harrowings by tyne cultivator + 1 harrowing by blade harrow. The highest uptake of N, P and K kg/ha were recorded in 1 harrowing by tyne cultivator + 1 roto till + residue. Higher values of available N, P and K kg/ha were noticed in zero tillage.

The highest output energy was obtained from 1 harrowing by tyne cultivator + 1 roto till + residue and input energy from 2 harrowings by tyne cultivator + 1 harrowing by blade harrow + residue. The output input ratio and energy use efficiency was higher under zero tillage with residue. All the soil physical properties *i.e.* soil moisture content, soil temperature, bulk density, porosity, hydraulic conductivity and rate of infiltration were significantly improved with deep tillage consisting of 2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Residue. The organic carbon, soil microbial biomass carbon, soil microbial biomass nitrogen and dehydrogenase activity was increased in tillage treatment of zero till + residue.

Effect of sequential application of pre- and post-emergence herbicides on weeds and productivity of ajwain

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A field experiment was conducted at Instructional farm, Rajasthan College of Agriculture, MPUAT, Udaipur during *Rabi* 2016-17 and 2017-18, to study the effect of sequential application of pre and post-emergence herbicides on weeds and productivity of ajwain. The experiment consists of nine weed management treatments comprising of pendimethalin 1000 g/ha *fb* hand weeding at 50 DAS, pendimethalin 750 g/ha *fb* quizalofop-ethyl 40 g/ha, oxadiargyl 100 g/ha *fb* hand weeding at 50 DAS, oxadiargyl 100 g/ha *fb* quizalofop-ethyl 40 g/ha, oxyfluorfen 100 g/ha *fb* hand weeding at 50 DAS, oxyfluorfen 100 g/ha *fb* quizalofop-ethyl 40 g/ha, one hand weeding at 25 DAS, two hands weeding at 25 and 50 DAS and weedy check. The experiment was laid out in a randomized block design with three replications. The soil of experimental field was clay loam in texture, slightly alkaline in a reaction medium in organic carbon, nitrogen, phosphorus and high in potassium. Ajwain variety AA-1 was taken as test crop and the crop. Application of herbicides was done as per treatments with manually operated knapsack sprayer with flat fan nozzle using the recommended volume of water. The data revealed that minimum weed density and dry matter at 60 DAS was recorded by weed management practice of two hands weeding at 25 and 50 DAS. However, it was closely followed by pre-emergence application of oxadiargyl 100 g/ha *fb* hand weeding at 50 DAS. Among the herbicidal weed management, application of oxadiargyl 100 g/ha *fb* hand weeding at 50 DAS recorded maximum weed control efficiency (84.51%) at 60 DAS, which was statistically at par with oxadiargyl 100 g/ha *fb* quizalofop-ethyl (83.30%). Maximum seed yield (694 kg/ha) and net returns (` 59353/ha) were recorded by two hands weeding at 25 and 50 DAS which was statistically at par with oxadiargyl 100 g/ha *fb* hand weeding at 50 DAS (675 kg/ha and ` 58350/ha, respectively) and sequential application of oxadiargyl 100 g/ha *fb* quizalofop-ethyl (644 kg/ha and ` 57353/ha, respectively). The study concludes that pre-emergence application of oxadiargyl 100 g/ha *fb* hand weeding at 50 DAS and sequential application of oxadiargyl 100 g/ha as PE *fb* quizalofop-ethyl 40 g/ha as PoE at 3-4 leaf stage and two hand weeding at 25 and 50 DAS were appeared to be a equally promising and effective weed management practices for managing broad spectrum weeds and obtaining higher seed yield and profitability of ajwain.

Energy studies of various weed management practices under high density planting system of cotton

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The present investigation was conducted for *Kharif* season as efficacy of different weed management practices in high density planting system (HDPS) cotton for two consecutive years (2014-15 and 2015-16) in a claey in texture soil at cotton research centre Dr. P.D.K.V. Akola (Maharashtra) India. To evaluate the energy studies of various weed managements practices, *viz*. pendimethalin 38.7 CS PE at 1.25 kg/ha *fb* hoeing at 30 DAS and one hand weeding at 45 DAS, quizalofop-ethyl 5 EC at 0.075 kg/ha PoE 20-25 DAS (2-4 leaf weed stage) *fb* hoeing at 45 DAS, pyrithiobac sodium 10 EC at 0.075 kg/ha POE 20-25 DAS (2-4 leaf weed stage) *fb* hoeing at 45 DAS, pendimethalin 38.7 CS PE at 1.25 kg/ha *fb* quizalofop ethyl 5 EC at 0.060 kg/ha + pyrithiobac sodium 10 EC POE at 0.062 kg/ha POE (tank mix) (2-4 leaf weed stage), hoeing at 20-25 DAS *fb* glyphosate 71 G at 1.50 kg/ha as directed spray at 45 DAS, hoeing at 20-25 DAS *fb* glyphosate 71 G at 0.5 kg/ha as directed spray at 45 DAS, weed free check (2 weeding *fb* 2 hoeing), under HDPS cotton. The energy output from seed cotton yield and stalk yield of cotton crop was worked out by multiplying yields with their energy values and expressed as Mj/ha. The energy balance was worked out by deducting the energy input from the energy output for each treatment and expressed as Mj/ha. Energy balance/unit input= Energy balance/Energy input. The energy output per unit input ratio (Mj/ha) was estimated by dividing energy output values with input values.

The result revealed that significant enhancement in the energy output (84627 and 123742 Mj/ha), energy balance (73492 and120656 Mj/ha), energy balance per unit input (6.6 and 10.8 Mj/ha) and energy output per unit input ratio (7.60 and 11.11 Mj/ha) with application of 2 weeding *fb* 2 hoeing followed application of pendimethalin 38.7 CS PE at 1.25 kg/ha *fb* hoeing at 30 DAS and one hand weeding at 45 DAS energy output (80816 and 120221 Mj/ha), energy balance (69643 and 115993 Mj/ha), energy balance per unit input (6.2 and 10.4 Mj/ha) and energy output per unit input ratio (7.23 and 10.76 Mj/ha) among the rest of the treatments during both the years. However, lower value was observed with weedy check (control). This might be due to higher production of seed and stalk yield which is directly proportional to energy production.

Thus, cotton production with various weed management practices under high density planting technique significantly improved energy output, energy balance per unit input, energy output per unit input ratio realized that, efficient enough in term of energy consumption as appropriate energy management (avoid excess energy input consumption) favours to maximise energy output, energy balance with higher cotton production in rainfed areas with high density planting system under various weed management practices.

Theme 10

Herbicide residues, monitoring, mitigation mitigation and effect on non-target organisms in weed management

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Evaluation of different herbicide mixtures for post-emergent weed management in maize and their residual effects on succeeding mustard under rainfed conditions

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Field experiments were conducted at Advanced centre for Rainfed Agriculture (ACRA), Rakh Dhainsar, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu to study the effect of evaluation of different herbicide mixtures for post emergent weed management in maize and their residual effects on succeeding mustard under rainfed conditions. Initially the experiment was laid out in a randomized block design with fifteen herbicidal treatments with three replication and five different herbicides were used during *Kharif season* of 2016-17and 2017-2018. The soil of the experimental field was sandy loam, low in organic carbon, slightly alkaline in pH, available phosphorus and potassium low and low in available nitrogen. During the crop growth periods the temperature conditions were more favourable during first *Kharif* season of 2016 as compared to *Kharif* season of 2017. All recommended agronomic practices were followed throughout the crop period. The dry biomass yield was recorded from the net plot area and expressed as t/ha. The experimental field was highly infested with *Digitria sanguinalis Acrache racemosa, Eragrstia tenella, Eleusine aegyptiacum, Echinachloa colonum, Cynodon dactylon Cyperus rotundus, cyperus Iria, Amaranthus viridis, commelina benghalensis, physalis minima* and *solanum nigrum,* and *Phyllanthus niruri* in maize crop where as mustard crop infested with *Asphodelus Tenuifolius, Fumaria parviflora, Chenopodium Album* and *Cynadon Dactylon.* Herbicidal mixture treatments Tembotrione 100 g/ha + atrazine 500 g/ha 15-20 DAS and Tembotrione 100 g/ha + atrazine 750 g/ha 15-20 DAS not only reduced the total weed population, weeds dry weight and weed index but also increased the weed control efficiency, plant height, cob/plant, grains/cob, plants/m^2, grain and stover yields which was at par withTembotrione 100 g/ha + halosulfuron 67.5 g/ha, tembotrione 100 g/ha + halosulfuron 52.5 g/ha at 15-20 DAS and atrazine 1000 *fb* tembotrione 100 g/ha. Highest net returns of ` 44,194/ha and 43,705/ha were obtained with Tembotrione 100 g/ha + atrazine 500 g/ha 15-20 DAS and Tembotrione 100 g/ha + atrazine 750 g/ha 15-20 DAS where as B:C ratio of 3.13 and3.12 were also obtained with the treatment Tembotrione 100 g/ha + atrazine 750 g/ha 15-20 DAS and Tembotrione 100g/ha + atrazine 500 g/ha which was at par with the treatment Tembotrione 100 g/ha + halosulfuron 67.5 g/ha net return and B:C ratio (` 38,746 and 2.57), tembotrione 100 g/ha + halosulfuron 52.5 g/ha at 15-20 DAS net return and B:C ratio (` 39,279 and 2.65) and atrazine 1000 *fb* tembotrione 100 g/ha net return and B:C ratio (` 43,038 and 3.03). Higher nutrient removal by maize was also recorded in Tembotrione 100g/ha + atrazine 500 g/ha 15-20 DAS and Tembotrione 100 g/ha + atrazine 750 g/ha 15-20 DAS respectively.

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Efficacy of pendimethalin 30 EC against *Phalaris minor* retz. in heavy textured soils

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Wheat (*Triticum aestivum* L.) is important food grain crop being a staple diet. It is leading among cereals and is a main source of carbohydrates and protein for both human beings and animals; contains starch (60-90%), protein (11-16.5%), fat (1.5-2%), inorganic ions (1.2-2%), and vitamins B-complex and vitamin E. Due to development in cultivation technologies like high yielding varieties, best irrigation facilities, fertilizer use, availability of high yielding varieties and mechanization, has drastically increased the crop productivity. In India, Punjab is having the highest wheat yield (5.05 t/ha, 2016-17) which is also partially due to the use of a wide range of chemical pesticides (herbicides, insecticides, fungicides) to reduce yield losses due to weed competition, insects and fungal diseases. But, now a days, the major bottle necks in wheat production is the development of multiple herbicide resistance in *Phalaris minor* Retz. It has been observed that *P. minor* has become most problemetic weed of wheat due to resistance against different post-emergence herbicides because of faulty spray technologies, use of non recommended herbicides and inefficacy of pre-emergence herbicides. Soil with high clay content and cation exchange capacity adversely affects the absorption and translocation of the herbicides, therefore, these soils requires higher doses of herbicides. The soils with high clay content bounds the chemical with the clay content which affects the efficacy of the herbicide. It is further reported in the literature that the efficacy of pendimethalin is reduced due to soil texture, use of less quantity of water, untimely application *etc.*

Therefore, an experiment was conducted to study the efficacy of pendimethalin 30 EC in heavy textured soils with the objective to efficiently control the *P. minor* Retz. In Punjab, the soils of the district Fatehgarh Sahib fall in Sadhugarh series of soils. These soils are having high clay content and very low pH that affects the herbicide performance. Therefore, three herbicide doses of pendimethalin 30 EC at 2.5 L/ha (already recommended by PAU, Ludhiana for Punjab conditions), 3.75 L/ha and 5.0 L/ha were tested against weedy check. The experiment was laid in randomized complete block design and replicated at three locations. The data for *P. minor* population and weed biomass was recorded at 30 days after herbicide application with metre square quadrant. It was observed that pendimethalin at 5.0 L/ha effectively controlled the *P. minor* population (1.6 plants/m^2) which was statistically at par with pendimethalin at 3.75 L/ha (2.40 plants/m^2). But significantly higher *P. minor* population and *P. minor* biomass with pendimethalin at 2.5 L/ha (3.4 plants/m^2) and weedy check (5.2 plants/m^2) was recorded. Similar results were obtained for weed biomass. The grain yield of wheat crop recorded with pendimethalin 30 EC at 3.75 L/ha was 2.5% higher than recorded in pendimethalin 30 EC at 2.5 L/ha. So application of pendimethalin at 3.75 L/ha efficiently controlled the *P. minor* in wheat.

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Optimizing pre-emergence herbicide oxyflourfen dose based on sorption and desorption studies for effective weed control in different soil types

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Adsorption and subsequent release of pre-emergence herbicide in to the soil solution decides the herbicide availability to kill the weeds. It is an important process for determining the ultimate fate of herbicides in soil. The interaction between herbicide chemistry and soil properties greatly affects its weed control efficacy and the potential for crop injury. Adsorption decreases the concentration of chemical in soil solution and decrease bioavailability. Desorption of herbicide is also critical in determining the herbicide available to the target species. Generally blanket recommendation is followed in India for weed control in various crops. Indian soils are very greatly in types with diverse organic matter content. Herbicides applied on clay or organic rich soil type are absorbed resulting in lower availability in soil solution that makes sub lethal to kill the weeds. Continuous exposure to mild and sub lethal dose leads to herbicides resistant weeds. Effective weed control could be achieved by studying the variability of soil and deciding the dose based on the sorption and desorption property of the soil. With this information on the background a laboratory experiment was conducted in the Department of Agronomy, Agricultural College and Research Institute, Madurai during 2016-2017 to study the optimum level of the pre-emergence herbicide oxyflourfen concentration in soil solution required to kill the weeds effectively. The study on sorption and desorption was carried out with pre-emergence herbicide oxyflourfen at 1, 2, 3, 4, 5 ppm concentration with five different soils *viz.*, sandy loam, sandy clay loam, clayey soil, sandy clay and sandy clay loam with high organic matter. Based on results obtained, sorption of pre-emergence herbicide oxyflourfen varied from 98.53 to77.96% in different soils. The highest sorption of 98.53% was observed with clayey soils followed by sandy clay loam soils with high organic matter content (96.97%). Lowest sorption (77.96%) was recorded with sandy loam soils. Highest desorption of 57.44% was recorded with sandy loam soil and the lowest desorption percentage (13.18%) was obtained with sandy clay loam soil with higher organic matter. Based on the analytical results of sorption and desorption, oxyflourfen dose was optimized as 0.53 kg/ha for sandy clay loam soils with high organic matter, 0.34 kg/ha for clay soil, 0.29 kg/ha for sandy clay, 0.21 kg/ha for sandy clay loam soil and 0.12 kg/ha for sandy loam soils. In conclusion the clay soil required more quantity of oxyflourfen compared to other type of soil for effective management of weeds under irrigated condition.

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Soil biology as influenced by herbicidal application

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Weeds are one of the major biotic constraints in crop production and weed control as an age old practice was achieved by manual and mechanical means with the involvement of soil cultivation which was effective in reducing weed incidence. But owing to soil disturbance, a number of detrimental side effects like risks of soil erosion and loss of organic matter were also increased. To overcome these hazardous effects which is the result of repeated soil cultivation, farmers started adopting minimum and conservation tillage. This shift towards conservation tillage required the use of alternative weed control strategies like herbicidal usage. The herbicide use is predicted to increase as the food production intensifies with a decrease in availability of labour for manual weed control especially in developing countries. So, herbicide application has become an integral part of vibrant agricultural productivity in the whole world since its benefit has been overwhelming over the years. The intensive use of herbicides has become a matter of environmental concern, partially because of the potential hazards of these on the soil biological processes and other non-target organisms. The soil serves as the repository for all agricultural contaminants, function as a major habitat for most microbial communities such as soil bacteria, fungi and actinomycetes whose activities influences the soil fertility. Out of the several biological parameters used to assess soil quality and health as affected by agricultural practices, microbial activity is expected to be more efficient indicator than physical and chemical parameters as they are able to respond immediately to the environmental changes. Indices of microbial population mostly used to assess the effects of herbicides include plate counts of aerobic heterotrophic bacteria, soil respiration rate, enzyme activities, *etc.* It has been observed that over application of herbicides inhibit some of the natural processes in soils, and decreases the performance of the non-target organisms. However, some soil organisms use these herbicides in the process of degradation as a carbon source for their metabolic activity. Herbicide application can affect soil respiration, emissions of other green house gases, rates of organic matter decomposition, C and N mineralization, enzymatic activities and substrate utilization patterns. But the magnitude and direction of these responses differ widely as per the herbicide applied and can be modulated by the identity and dose of the herbicide, the timing of application, exposure time, inherent microbes population and chemical as well as physical characteristics of soil. The impact of herbicides on soil biology and its functionality is a complex issue as all the herbicides though belonging to the same group does not guarantee to have similar impacts on soil organisms. But a majority of workers have reported that negligible impacts of herbicides on soil microbial communities and beneficial soil functions when applied at recommended dose which is in contrast to the altered population dynamics and microbial activities in soils receiving herbicide inputs of 5-100X recommended dose. So, there is a strong need for a framework for assessing the meaningful endpoints to these studies.

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Mitigation of herbicide residues in soil through Biochar: A Review

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Application of biochar is a very good option to temporarily immobilize the herbicide residues in soil and allow the crop to escape from toxicity. The source of material used for biochar production also affects the sorption of herbicide residues. Biochar addition, even in small quantity, increased diuron sorption. Thus, the presence of carbonaceous material, even in small amounts, can dominate sorption of organic compounds in soils (Janaki *et al*. 2015).

Biochars produced from different feedstocks and under different conditions were used as soil amendments instead of activated charcoal (AC). The various biochar properties, specific surface area of biochar was measured by nitrogen surface sorption, using a Carlo Erba Sorptomatic 1900 (Carlo Erba Instruments, Rodano, Italy) and the Brunauer, Emmett, and Teller (BET) method on a previously degassed 0.2 g sample at 80°C for 24 h. The pH was determined in a 1:5 biochar/deionized water slurry. Carbon and nitrogen contents were determined with ASTM method D5373-08. Dissolved organic carbon (DOC) from biochar was characterized briefly; DOC was extracted with 0.01 M $CaCl_2$ at 1:20 solid/solution ratio as duplicates. DOC in the extracts was measured with a Shimadzu-V CSH analyzer (Shimadzu, Kyoto, Japan). Extracts were diluted when absorption values were higher than 0.1/cm to avoid matrix effects. Emission fluorescence ranging from 300 to 480 nm of the extracts (adjusted pH=2) and excitation at 254 nm was determined in an F-2500-FL-spectrophotometer by Hitachi (Tokyo, Japan).

The objective of this review paper was to determine the effect of biochars made from different feedstocks and with different characteristics on the sorption–desorption of three chemical classes of pesticides, two of which are highly mobile herbicides and third is a toxic fungicide. We also evaluated the efficacy of these biochars as soil amendments to reduce potential environmental pollution associated with the use of pesticides by increasing its sorption and reducing its mobility. The pesticides selected for this study were: i) bentazone, a post-emergence selective herbicide used to control broad-leaf weeds in crops such as alfalfa, corn, rice, sorghum, and soybeans; ii) aminocyclopyrachlor, approved for the control of broad-leaf weeds, grasses, vines and woody species in non-crop, turf, sod farms and residential areas; and iii) pyraclostrobin, a strobilurin type fungicide with protectant, curative and translaminar properties, which is widely used in several crops, including grape, cereals, citrus, potato, tomato and turf. Despite its links to naturally produced compounds in white rot fungi, pyraclostrobin is considered very toxic for aquatic organisms (Cabrera *et al*. 2014).

Persistence of atrazine in soil and its residue analysis in maize crop at harvest

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Maize is one of the most important cereal crops of the world and contributes to food security in most of the developing countries. In India, maize is emerging as third most important crop after rice and wheat. Its importance lies in the fact that it is not only used for human food and animal feed but at the same time it is also widely used for corn starch industry, corn oil production, baby corns *etc*. It is grown over 4 per cent of the net area sown of the country and accounts for ~9 per cent of total food grain production in the country. Losses due to weeds in maize yield production range from 33-50%, depending upon weed infestation. Atrazine (2-chloro-4-ethyl amino-6-isopropyl amino-1, 3, 5 triazine), a sym-triazine group member is soil applied herbicide. It has widespread usage as pre-emergence control on a wide variety of grasses and broad-leaved weeds in cropped and non-cropped areas. Atrazine it is readily absorbed by the roots and translocated to the leaves and moves rapidly to the shoot via the apoplast and concentrate first in the veins then in the interveinal areas and finally in the margins of leaves. Atrazine inhibits the photosynthesis PS II at site 1 in weeds. The specific site of action is oxygen evolution step or photolysis in photosynthesis.

Atrazine was applied in *Rabi* season under field condition. Two treatments consisting of atrazine at recommended (2 kg/ha) and double recommended (4 kg/ha) doses along with control were arranged in a randomised block design with three replications. Soil samples (0–15 cm depth) were collected from all plots at different time intervals to harvest time while, maize crop were taken at harvest. Samples were extracted with dichloromethane: acetone solution mixture thrice, concentrated under pressure on rotary evaporator and subjected for cleanup via solid phase extraction. Atrazine residues were analysed by RP-HPLC at 280 nm using C-18-ODS-II column and mobile phase actonitrile: water [40:60% v/v].

The recovery of atrazine from soil, maize cobs and straw were in the range 87.2-91.6, 88.8- 92.0, and 91.0-95.65, respectively. Atrazine persistence in soil was more than 100 and 135 days at lower and higher application dose, respectively after which it was below detectable. Dissipation of atrazine followed first order kinetics. Half-life values calculated for atrazine was 16.45 days for lower application rate and 20.30 days for higher rate. At harvest atrazine residues were below detectable limit in soil, maize cobs and maize plant/straw. The limit quantification of atrazine was 0.001, 0.005 and 0.01 µg/g for soil, cob and straw.

It was concluded that post-emergence application of atrazine is safe even at double dose for human and environmental aspects as residues were below MRL in soil, maize grain and straw.

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Adsorption and desorption of metribuzin in tomato growing soils

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Metribuzin [4-amino- 6-tert-butyl- 4, 5-dihydro-3- methylthio-1, 2, 4- triazinone] is an asymmetric triazine, selective herbicide used as a pre- and post-emergence herbicide to control large number of grass and broad-leaved weeds infesting agricultural crops such as soybean, sugarcane, maize, wheat and vegetables including tomato, potato and carrot. In Telangana state, metribuzin is the most widely used post-emergence herbicide by tomato farmers. Adsorption-desorption is a surface phenomenon and one of the important physico-chemical processes that directly and indirectly influence the fate of the herbicide in the soil. Persistence of metribuzin in soil is determined by its rate of adsorption to soil particles, which is closely related to the organic matter content of the soil. Other soil characteristics, such as soil moisture, temperature and acidic conditions also influence the persistence and adsorption. To study the adsorption and desorption of metribuzin, three soil samples were collected from farmer's fields with different physical and physico-chemical properties (pH, Electrical conductivity, organic carbon, cation exchange capacity and texture). One sample (S-1) was clayey in texture with alkaline pH and CEC of 31.3 mol (p+)/kg. Second sample (S-2) was sandy laom in texture with slightly acidic reaction and CEC of 13.9 mol (p+)/kg, whereas third sample (S-3) was clay loam in texture with slightly alkaline reaction and CEC of 24.2 mol (p+)/kg. Adsorption experiment was carried out adopting the batch equilibrium protocol. The adsorption data of all the three soil samples for metribuzin fitted well with Freundlich equation. The adsorption isotherms were mainly parabolic in nature with 'S' shaped character. The K_f (Freundlich adsorption coefficient) values for the soils were 0.729 (S-1), 0.062 (S-2) and 0.209(S-3). The 'K_f' values were positively and significantly correlated with organic carbon and clay content. The K_{doc} (Soil organic carbon- water distribution coefficient) values for metribuzin in soils were 74.64(S-1), 35.48(S-2), 121.70(S-3). The desorption K_f values varied between 0.988 (10 µg/ml) to 7.930 (50 µg/ml) in S-1; 0.019 (10 µg/ml) to 0.385 (50 µg/ml) in S-2 and 0.237 (10 µg/ml) to 2.930 (50 µg/ml) in S-3. There was a consistent increase in K_f value as the initial concentration increased in all the soils which is an indicative of difficult desorption of metribuzin. The per cent desorption varied between 23.93 to 50.18% in S-1; 51.81 to 78.34% in S-2 and 37.42 to 66.34% in S-3 sample. The content desorbed for each initial concentration of metribuzin was found to decrease with the increase in clay content and organic carbon. Desorption data indicated that hysteresis was the highest in S-1 and the lowest in S-2 and intermediate in S-3, which specified that, desorption in the soil is strongly influenced by the clay and organic matter content. Adsorption of metribuzin was significantly and positively correlated with organic carbon, clay content and clay + organic carbon content of the soil and the adsorption was not completely reversible.

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Soil microbial population in response to applied herbicides in greengram

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Application of herbicides leads to unseen fluctuations in microbial population present in soil which can disturb their ecological balance. This paper focuses on the fluctuation of different kinds of microbial population with time due to application of pre- and post-emergence herbicides in greengram. The study included estimation of population of total heterotrophic bacteria, fungi, actinomycetes, symbiotic nitrogen fixing bacteria and free living nitrogen fixing bacteria in soil as affected by different herbicidal treatments. Almost all the herbicides treated plots brought the microbial load down after 16 DAS. But application of oxyfluorfen instead of negatively affecting the microbial population, raised it even more than that of control where no herbicidal treatment was done except in case for actinomycetes and symbiotic nitrogen fixing bacteria. Also a sharp fall of microbial load was seen when the dose of herbicide was increased. This indicates the negative impact of herbicides on soil microflora which can in turn affect the soil health and sustainability of production system. It was found that the microbial population (MP) was significantly different among the treatments due to different modes of action of the herbicides and their doses taken. The general trend in all the treatments including the control was that the microbial load (ML) increased with time, reaching a peak at 14-20 DAS and then decreased gradually till harvest of the crop (while in some cases there was a sharp fall). This might be due to the reason that with the rapid increase in biomass of the crop with time the MP also increased owing to the increased root exudation and biomass production of the crop and hence, the availability organic matter content and carbon and energy sources for microbial growth. While in later stages of crop where the rate of biomass production decreased, the MP also declined which might be due to increased competition among microbes for food and energy. Thus, it is expected that nutrient release would also have increased in early stages of crop. But due to application of pre-emergence herbicides, the ML started declining after 16 DAS although the crop biomass kept increasing. This was found in all the treatments indicating the death of microbes due to herbicide molecules. Application of herbicides negatively affects the microbial population of soil challenging the maintenance of ecological balance and soil health. Some molecules like oxyfluorfen have phytotonic effects to some extent while rest of the herbicidal treatments reduced the microbial load. This means that the rate of nutrient release in soil will also be retarded due to microbial deaths. In case of pulses like greengram the death of nitrogen fixing bacteria can lead to yield reduction. Thus, new ways to manage weeds must be carved out which can reduce reliance on chemicals and be nature friendly.

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Evaluation of potential risk of sulfosulfuron residues in wheat

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Wheat is an important cereal crop of Himachal Pradesh. Invasion by wide range of grassy and non grassy weeds is one of the major factors for reducing yield of wheat crop. Among herbicides, sulfosufuron is one of the selective post emergence herbicide belonging to sulfonylurea class of herbicides, which provide effective control of weeds in wheat. The fate and environmental behavior of applied herbicide is of concern as studies have shown that the extremely low levels of sulfosulfuron residues have phytotoxicity to sensitive crops in crop-rotation systems. Therefore, to obtain a better understanding about the fate of sulfosulfuron in soil and its residues in crop produce, a field experiment was conducted with wheat crop to evaluate the persistence and harvest time residues of sulfosulfuron in wheat. Post-harvest soil (0-15 cm depth) and wheat grain samples were collected from three treatments of sulfosulfuron applied in field *viz*. 10 g/ha, 20 g/ha and 40 g/ha along with control. The residues of sulfosulfuron extracted from the collected samples after cleanup were estimated in laboratory by HPLC equipped with PDA (Photo Diode Array). The retention time for sulfosulfuron was found to be 2.26 minutes. The Instrument detection limit (IDL) for sulfosulfuron was 0.004 µg/ml and estimated method detection limit (EMDL) for soil, wheat grain and straw was calculated as 0.001 µg/g. At fortification levels 0.25, 0.5 and 1 µg/g, the per cent recoveries of sulfosulfuron were 80.0, 79.0 and 81.0 in soil, 77.6, 76.0 and 78.0 in wheat grain; and 78.4, 78.0 and 77.0 in wheat straw respectively. The degradation of sulfosulfuron in soil exhibited first order kinetics for all the three application rates. More than 75 per cent of applied herbicide at 10 g/ha, 20 g/ha and 40 g/ha dissipated from soil within 15 days after herbicide application. The values of half-lives for applied sulfosulfuron treatments *i.e.* 10 g/ha, 20 g/ha and 40 g/ha in soil varied from 1.80, 2.92 and 11.58 days respectively. At 30 and 45 days after herbicide spray, residues were below detectable limit at lower doses *i.e.* sulfosulfuron 10 and 20 g/ha whereas, at higher dose *i.e.* 40 g/ha residues were found to be 0.060 µg/g and 0.002 µg/g respectively which indicated that sulfosulfuron at higher dose persisted in the soil for longer periods than at lower doses. The residues of sulfosulfuron were below detectable levels (d" 0.001 µg/g) in both straw and grain samples at harvest.

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Azotobacter spp. use as beneficiary response on crop growth rate

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Biofertilizers are defined as preparations containing living cells or latent cells of efficient strains of micro organisms that help crop plants' uptake of nutrients by their interactions in the rhizosphere when applied through seed or soil. They accelerate certain microbial processes in the soil which augment the extent of availability of nutrients in a form easily assimilated by plants. It is the important and well known free living nitrogen fixing aerobic bacterium. It is used as a Bio-Fertilizer for all non-leguminous plants especially rice, cotton, vegetables *etc*. *Azotobacter* cells are not present on the rhizosplane but are abundant in the rhizosphere region. The lack of organic matter in the soil is a limiting factor for the proliferation of *Azotobacter* in the soil (Jackson and Paterson 2000; Shaner, 1991, 2000b, 2001a). These bacteria utilize atmospheric nitrogen gas for their cell protein synthesis. This cell protein is then mineralized in soil after the death of *Azotobacter* cells thereby contributing towards the nitrogen availability of the crop plants. *Azotobacter* spp. is sensitive to acidic pH, high salts, and temperature. *Azotobacter* has beneficial effects on crop growth and yield through, biosynthesis of biologically active substances, stimulation of rhizospheric microbes, producing pathogenic inhibitors. Modification of nutrient uptake and ultimately boosting biological nitrogen fixation.

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Residues dynamics of herbicides in water and fishes and subsequent effects on water quality and fish mortality

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The persistence of herbicides in the aquatic body is important as well as their ultimate fate. The length of time which the herbicide and other pollutants persist in the soil, crop produce and water determines the length of exposure. Continuous use of herbicides near the aquatic area has prompted various concerns of the effects of these chemicals on the life stages of fish and other aquatic lives. If a herbicide is toxic to the early life stages of fish is used annually or continuously, the herbicide could contribute to a decline in the fishery of a aquatic body. Generally, herbicides find ways to water sources through runoff, drift, soil erosion, leaching, and occasionally, accidental or deliberate release. Therefore, in this study, residues dynamics and effect of herbicides namely, anilofos, oxyfluorfen and butachlor on water quality and fish morality were evaluated. Herbicides, butachlor at 1.5 kg/ha, oxyfluorfen and anilofos at 0.400 and 0.250, kg/ha, respectively were applied in *Kharif* to the paddy crop field adjacent to the ponds. After each natural rain, herbicide entered into the adjacent pond water through runoff water. Water and fishes samples were collected after herbicide application and rain events in *Kharif* between 0 to 100 days to determine the bioaccumulation and persistence of herbicides. Effect of herbicides on water quality was also evaluated in the respective days. Fish mortality and toxicity symptoms were recorded initially in the pond where herbicides entered through runoff water. Samples were processed and analyzed for herbicides residues by HPLC as described by Sondhia (2014). An amount of 0.0452 to 0.021 µg/g of oxyfluorfen, 0.0152 to 0.042 µg/g of anilofos residues, and 0.0116 to 0.0014 µg/g of butachlor residues were detected from fishes collected between 0 to 90 days in *kharif* season. Herbicides were persisted up to 90 days in the fishes. Maximum fish mortality was recorded in those ponds where butachlor was entered through runoff water followed by anilofos and oxyfluorfen. Effect of butachlor was more on fish mortality and on gills and eyes of fishes were mainly affected by butachlor application. An amount of 0.022 to 0.0025 µg/ml, 0.137 to 0.0036 µg/ml and 0.151 and 0.0064 µg/ml residues of oxyfluorfen, butachlor and anilofos, respectively were detected in pond water between 0 to 90 days. Herbicide dissipated slowly in water as compared to soil. pH, TS, TDS of pond water were increased and there was little variation on dissolved oxygen after application of oxyfluorfen and anilofos. Electrical conductivity of pond water was decreased after passage of time. These results showed that care should be taken while applying these herbicides in agricultural fields near the aquatic fields.

Theme 11

New herbicides molecules/formulations and low dose herbicides including nano-herbicides

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Efficacy of bentazone as post-emergence against weeds in direct-seeded rice

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A field experiment entitled "Efficacy of bentazone as post-emergence against weeds in direct-seeded rice" was conducted during *Kharif* season of 2017. The rice variety '*IR-36'* was used for sowing in the experimental field and it matures in 110-120 days. The experiment consist of total ten treatments comprising of seven doses of bentazone (600, 800, 1000, 1200, 1800 and 2000 g/ha) and application of 2,4-D (380 g/ha) as post-emergence, hand weeding twice at 20 and 40 DAS including weedy check, were laid out in randomized block design with three replications. The crop was sown on July 7th, 2017 and the herbicidal treatments were applied on July 22nd, 2017 and crop was harvested on October 24th, 2017. The soil of experimental site was Sandy Clay loam in texture, medium in organic carbon (0.62%), available nitrogen (285 kg/ha), available phosphorus 17.45 kg/ha) and potassium (260 kg/ha) with neutral pH (7.1). The dominant weeds associated with direct seeded rice in the experimental field were mainly comprised of monocot weeds (*Echinochloa colona* and *Cyperus iria)* and dicot weeds (*Mollugo pentaphylla, Phylanthus niruri, Eclipta alba, Corchorus olitorius* and *Alternanthra philoxeroides)* present in weedy check plots. Among the herbicidal treatments, activity of bentazone against narrow leaved weeds was poor whereas, the significant reduction in the density of dicot weeds was well marked when it was applied at the lowest dose (600 g/ha), but when it was applied at the rate of 800 to 2000 g/ha as post-emergence, it controlled the associated dicot weeds in plots to great extent. Weedy check had the highest weed biomass, it reduced significantly when weeds were controlled either chemically or mechanically. The lowest weed biomass was recorded under hand weeding treatment, which proved significantly superior to all the herbicidal treatments. Among the herbicidal treatments, application of bentazone at the rate of 1800 and 2000 g/ha as post-emergence arrested the weed biomass production of dicot weeds remarkably and proved superior to its lower dose (600 g/ha) and check herbicide 2, 4-D. The highest weed control efficiency (98.28%) was noted under hand weeding treatment due to the lowest weed biomass production. Both grain and straw yields were significantly higher under all the plots receiving weed control measures than weedy check plots. Bentazone applied at the rate of 800 g/ha recorded higher grain and straw yields compared to other doses of bentazone (600, 1000, 1200, 1600, 1800 and 2000 g/ha) and check herbicide 2, 4-D (380 g/ha) but all these were inferior to hand weeding twice. As regards the economics less expenditure was incurred under herbicidal treatments as compared to hand weeding twice. Though the gross monetary returns was higher under hand weeding twice but the application of bentazone at the rate of 800 g/ha gave the highest net monetary return and B:C ratio, indicating that bentazone applied at the rate of 800 g/ha as post-emergence was suitable and profitable in direct seeded rice of Jabalpur condition.

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Influences of new herbicide molecules on productivity of rice in Jharkhand

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"Rice is life" is most appropriate for India as this crop plays a vital role in national food security. Among various production factors, weeds play a vital role in limiting the production of rice as presence of weeds reduces the grain yield by 20-25% in transplanted rice. The experiment was conducted in plot no 45 located in the Western section of rice agronomical research farm of Birsa Agricultural University, Ranchi, Jharkhand. The experimental plot was typical medium paddy land having well drained soil with uniform topography. Geographically, agronomical research farm of Birsa Agricultural University, Ranchi, Jharkhand is situated at 23°17´ N latitude and longitude of 85°10´ E with an altitude of 625 m above the mean sea level. The experimental site, Ranchi comes under the VII Agro-climatic region of India *i.e.* eastern plateau and hills which is termed as sub-humid with hot summer and cold winter. The source of rainfall is south-western monsoon. It receives an average annual rainfall of 1326 mm (based on 80 years mean), mostly (85%) concentrated during the period of June to September. A few showers are expected during winters and occasionally during summer months. May and June are the hottest months with average maximum temperature of 35.6ÚC and 36.2ÚC, respectively. The present investigation entitled "Effect of new herbicides on yield attributes, yield and profitability in transplanted rice (*Oryza sativa* L.)" was carried out during *kharif*, 2013 at Birsa Agricultural University Farm, Ranchi, Jharkhand on clay loam soil having low in organic carbon (0.37%) and available nitrogen (253.4 kg/ha) whereas medium in available phosphorus (15.9 kg/ha) and potassium (137.5 kg/ha) with moderately acidic (pH 6.1). The experiment was laid out in a randomized block design with ten treatments replicated four times. Application of flucetosulfuron 20 g/ha alone or in combination with bispyribac sodium 25 g/ha produced almost similar number of effective tillers (272 and 278/m^2, respectively) as weed free (295/m^2). Similarly, grains/panicle under flucetosulfuron 20 g/ha alone or in combination with bispyribac sodium 25 g/ha (177 and 180, respectively) was as high as weed free (186) and were significantly higher to mechanical and hand weeding. Grain yield of rice with application of flucetosulfuron 20 or 25 g/ha *fb* by bispyribac sodium 25 g/ha was as high (5.46 and 5.59 t/ha, respectively) as in weed free (5.85 t/ha). Further, application of flucetosulfuron 20 g/ha alone at 3 days after transplanting produced similar grain yield (5.27 t/ha) as in combination with bispyribac sodium 25 g/ha and was significantly higher than application of bispyribac sodium 25 g/ha alone as well as hand weeding to the tune of 11 and 22%, respectively. Application of flucetosulfuron 20 g/ha alone had significantly higher net return to the tune of 22% and 42% over mechanical and hand weeding, respectively.

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Weed studies in aerobic rice under different herbicides and herbicide combinations

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The field investigation entitled "Integrated weed management in aerobic rice (*Oryza sativa* L.)" was conducted during *Kharif* season of 2013-15 at Upland Paddy Research Scheme Farm, Vasantrao Naik Marathwada Agricultural University, Parbhani with an object to find out best method of weed management under aerobic rice and to develop cost effective weed management in aerobic rice system. The experiment was laid out in Randomized Block Design (RBD) with eleven treatments. The treatment were T_1 -POE-Byspyribac-sodium (10% SC) at 35 g/ha at 15-20 DAS, T_2 -POE-Byspyribac-sodium (10% SC) at 35 g/ha at 15-20 DAS + one hoeing at 45 DAS, T_3 -PE-Pendimethalin (30 EC) at 1.00 kg/ha at 3-4 DAS + POE-Bispyribac-sodium (10%SC) at 35 g/ha at 15-20 DAS, T_4 -PE-Butachlor (50 EC) at 1.5 kg/ha at 3-4 DAS + POE-Bispyribac-sodium (10%SC) at 35 g/ha at 15-20 DAS, T_5 -PE-Pendimethalin (30 EC) at 1.00 k*g/ha* at 3-4 DAS + POE-MSM+CME (20 WP) at 40 g/ha at 25-30 DAS, T_6 -PE-Butachlor (50 EC) at 1.00 kg/ha at 3-4 DAS + POE-MSM+CME (20WP) at 40 g/ha at 25-30 DAS, T_7 -POE-Azimsulfuron at 20-30 g/ha at 20 DAS, T_8 -PE-Butachlor at 1.00 kg/ha + 1 HW at 30 DAS, T_9- 2 HW at 20 & 45 DAS + 2 hoeing at 25 & 45 DAS, T_{10} -3 Need based hand weeding, T_{11} -Unweeded control. Each treatment was repeated three times having gross and net plot size of 4.0 x 4.5 m and 3.0 x 3.6 m, respectively. Variety used for experimental study was PBNR-03-02 with recommended dose of fertilizer of 80:50:50 NPK kg/ha and 60 kg seed rate/ha. Sowing was done by hand drilling on 02nd July, 2013.

Amongst herbicides and integrations of herbicide with cultural practices or herbicide, PE-Butachlor at 1.00 kg/ha + 1 HW (T_8) recorded the lowest weed count, weed dry weight, weed index (7.69) and highest weed control efficiency (68.55%) than rest of the herbicide or integration of herbicides at 60 DAS. Amongst herbicides and combination of herbicides, PE-Pendimethalin (30 EC) at 1.00 kg/ha + POE-Bispyribac-sodium (10%SC) at 35 g/ha (T_3) recorded the lowest weed count, weed dry weight, weed index (10.25) and highest weed control efficiency (75.63%) than rest of the herbicides or combination of herbicides and was at par with PE-Butachlor (50 EC) at 1.5 kg/ha + PoE-Bispyribac-sodium (10% SC) at 35 g/ha (T_4) at 60 DAS. Per cent NMR loss due to unweeded control (T_{11}) was 90.01 in comparable to weed free plot. Per cent reduction in NMR weed free plot with PE-butachlor at 1.00 kg/ha + 1 HW (T_8) and PE-pendimethalin (30 EC) at 1.00 kg/ha + PoE-Bispyribac-sodium (10%SC) at 35 g/ha (T_3) was 6.14 and 11.05, respectively in comparable to weed free plot.

Development of mycoherbicide agaisnt *Eichhornia crassipes, Parthenium hysterophorus* and *Lantana camara*: Progress and future prospects

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The global need for weed control has been imposed mainly by the chemical industry. If herbicides are often effective and necessary to agriculture yet pose some serious problems particularly if they are misused. For example toxic and otherwise harmful compounds threaten animal and public health when they accumulated in food plants, ground waters and drinking water. A key approach in all sustainable weed management systems is to make the best possible use of the natural organism or their metabolites of each weed a known as biological control. Biological control of weeds involves the use of living organisms or their natural product to attack a weed population to keep at or below desirable level without significanlty affecting desirable plants. Weed pathogens are able to produce a wide array of toxins, bioactive metabolites with different biological activities, chemical structure, mechanism of action and specificity with respect to plants, environmental impact and stability. Some of the advantages of mycoherbicide over traditional chemical herbicides are their specificity for the target weed; absence of adverse effects on humans, wildlife or domestic animals rapid degradation and absence of residues in surface or ground water, crops, soil or food chains.

We have made significant progress in the development and application of mycoherbicide for weed *Parthenium hysterophorus, Lantana camara* and *Eichhornia crassipes*. We initiated s series of studies aimed to develop mycoherbicide for *Parthenium hysterophorus, Eichhornia crassipes* and *Lantana camara* weeds. A potential fungal stain coded AGWH#11 have been ioolated, mass produced, formulated and utilized in many ways with satisfactory results for control of water hyacinth. AGPH#04 was found to be pathogenic to *Parthenium hysterophorus* weed. It effectively controlled Parthenium during field applications. AGLC#14 was applied to control *Lantana camara*. The optimal growth and maximum phytotoxin production condtion of three isolates were investigated. Particular attention was given to maximize toxin production; scaling up the production in fermentation systems, purification and identification of herbicidal compounds. This paper will discuss the progress on these three fungi and their secondary metabolites application for the managment of *Parthenium hysterophorus, Eichhornia crassipes* and *Lantana camara* respectively.

Evaluation of the spraying techniques for low dose high potency herbicide molecules

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New generation herbicides are low dose high potency molecules that are decreasing the use of high dose low potency molecules. In other ways it reduces the environmental load. In order to successfully use herbicides, their application must be accurate and uniform. In general practice, the herbicides of liquid form are mixed with water and applied by low-pressure agricultural sprayers. A perfect nozzle-pressure combination with proper amount of spray volume influences the spraying efficiency and herbicide efficacy. Further, the suitability of the existing spraying technologies to the low-dose-high-potency herbicide molecules is unknown. Thus, the trend of shifting the herbicide use from high-dose to low-dose molecules necessitates the evaluation of existing spraying techniques. Thus, an experiment on evaluation of spraying techniques for low-dose-high-potency herbicide molecules was carried out at Jabalpur (23°13’47.0"N 79°58’11.7"E). A field experiment was conducted during *Kharif* and *Rabi* seasons of 2016-18 in rice and wheat to evaluate the spraying techniques. Low-dose-high-potency herbicide molecules, such as bispyribac-Na at 25 g/ha and clodinafop + metsulfuron at 60+4 g/ha was selected respectively for rice and wheat crop as post-emergence (PoE) herbicides along with different nozzle types and spray volumes for treatments. The experiment was conducted in a split-split plot design and replicated thrice. The treatment includes the weed management practices such as PoE *fb* 1 hand weeding (HW), PoE alone and weedy as main treatment, nozzle type such as flat fan (FF) and floodjet (FJ) as sub treatment and spray volume such as 500 and 250 L/ha as sub-sub treatments. It was found that, the different weed management practices significantly affect the crop growth, weed control and grain yield in both rice and wheat crop for all the years. The lowest weed density up to 4.5/m^2, weed dry weight up to 6.4 g/m^2 and highest grain yield up to 6.15 t/ha was recorded in PoE *fb* 1 HW in rice. Where as in wheat, the lowest weed density up to 4.8/m^2, weed dry weight up to 3.8 g/m^2 and highest grain yield up to 4.01 t/ha was recorded in PoE *fb* 1 HW. The weed control index for rice and wheat was more or less similar and no significant difference was observed among different nozzles and spray volumes. Therefore, based on obtained results from the experiment, the spraying volume can be reduced from 500 L/ha to 250 L/ha and flat fan or floodjet can be used for effective weed control.

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Efficacy of new herbicide for effective control of broad-leaved weeds in wheat in vertisols of central India

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Wheat (*Triticum aestivum* L.) being backbone of food security is widely grown in almost all parts of India. Due to change in climate and increased biotic and abiotic stresses, maintaining production and productivity upto required level is a big challenge. Among biotic stresses, weeds by putting great competition for resources with wheat crop, causes significant reduction in wheat yield and also impair the quality of produce. In weeds, although narrow leaved weeds are putting menace in many areas of Central India but still extent of infestation is high due to broad-leaved weeds. Moreover, most common herbicide like 2, 4-D for broad-leaved weeds sometimes puts adverse effect on wheat. Hence, to find out the efficacy of new herbicide for the control broad-leaved weeds of wheat crop in vertisols of Central India, present investigation was undertaken. This field experiment was conducted for two consecutive years during *Rabi* seasons of 2016-18 at ICAR-IARI, Regional Station, Indore. The soil of experimental site was medium black with pH value of 7.40, organic carbon (0.52%), available nitrogen (230.4 kg/ha), phosphorus (16.8 kg/ha) and available potassium (424.6 kg/ha). In this experiment, 11 treatments comprised with halauxifen-methyl ester + florasulam 40.85% WG + polyglycol 26-2 N (12.76 g/ha), metsulfuron-methyl (4 g/ha), carfentrazone (20 g/ha), 2,4-D Na (80 WP, 500 g/ha), 2,4-D E 38 EC (500 g/ha), metsulfuron + carfentrazone (4+20 g/ha), 2,4-D Na (80 WP) + carfentrazone (400+20 g/ha), 2,4-D E 38 EC + carfentrazone (400+20 g/ha), halauxifen-methyl + florasulam + carfentrazone (10.21+20 g/ha), weedy check and weed free were evaluated in randomized block design with three replications. Wheat cultivar '*HI 1544*' was used in the trial and all recommended package of practices were followed for a healthy crop. Data on weed dynamics indicated that broad-leaved weeds density observed at 30 and 60 days after spray (DAS) and dry weights at 60 and 90 DAS were decreased significantly in both the years as compared to weedy check. Application of halauxifen–methyl + carfentrazone at 30 DAS (92.5%) in first year and halauxifen–methyl alone during all other stages *i.e.* 60 DAS (95.8%) in first year and 94.6% and 96.6% during second year at 30 and 60 DAS, respectively, recorded highest values of weed control efficiencies. Halauxifen–methyl application also recorded lowest values of weed index to the extent of 2.12% and 1.91% during first and second years, respectively. Carfentrazone used as sole or in association of other chemicals caused phytotoxicity. Highest growth and yield attributes and grain yield (6.60 and 6.27 t/ha) and biological yield (15.24 and 14.67 t/ha) recorded with weed free treatment were at par with application of halauxifen–methyl but significantly higher over weedy check. Although, highest values of energy input (23.32 thousand MJ/ha), energy output (201.1 thousand MJ/ha), cost of cultivation (52.4 thousand/ha) and gross returns (142.4 thousand/ha) were recorded with weed free treatment but application of halauxifen–methyl gave maximum values of energy ratio (8.72), energy productivity (279.8 gm/MJ), net returns (92.8 thousand/ha) and benefit: cost ratio (2.99). Thus, concluded that post-emergence application of halauxifen–methyl can be done in wheat for efficient control of broad-leaved weeds and to fetch higher net returns and energy efficient productivity of wheat in vertisols of central India.

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Broad-leaved weed control in wheat through new herbicide combinations in the north-eastern part of West Bengal

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An experiment was laid out in Randomized Block Design with three replicates at the Instructional Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar, West Bengal during two consecutive years, *i.e. Rabi* 2016-17 and 2017-18. It has been reported that *Polygonum* spp. is a notorious weed in wheat instead of *Phalaris minor* in this belt which accounts for a major share of total weed flora. To broaden the spectrum of weed kill and to provide the long term residual weed control, the use of herbicide mixtures are advocated. Nine various herbicide combinations along with a weedy check and a weed free treatment were randomly allotted to various plots under each replication. The treatments included in the trial were: halauxifen-methyl ester + florasulam 40.85% WG + polyglycol 26-2 N; metsulfuron-methyl 20 WG + surfactant; carfentrazone 40 DF; 2, 4-D Na 80 WP; 2,4-D E 38 EC; metsulfuron + carfentrazone + surfactant; 2, 4-D Na + carfentrazone; 2, 4-D E + carfentrazone and halauxifen-methyl + florasulam + carfentrazone + surfactant. Wheat variety used in the experiment was K 0307.

During 60 days after sowing, *Polygonum* spp. alone constituted almost 72% of the total broad-leaved weed population in both the years of experimentation. All the herbicide combinations used in the experiment significantly reduced the broad-leaved weed population in different degree after 30 and 60 days of spraying of post-emergence herbicides. Among the herbicidal treatments, metsulfuron + carfentrazone + surfactant recorded significantly lowest weed population (9.0 and 0.0/m^2 in 2016-17 and 10.0 and 2.3/m^2 in 2017-18 during 30 and 60 days after spraying of post-emergence herbicides, respectively) among all herbicide combinations in both the years of investigation. The lowest weed dry weight at 30 and 60 days after spraying of post-emergence herbicides (10.1 and 0.0 g/m^2 during 2016-17 and 18.0 and 9.0 g/m^2 during 2017-18, respectively) was also achieved with metsulfuron + carfentrazone + surfactant treatment during both the years, which was statistically at par with 2,4-D E + carfentrazone treatment (11.6 and 27.8 g/m^2 during 2016-17 and 21.7 and 27.6 g/m^2 during 2017-18, respectively). At 30 and 60 days after spraying of post-emergence herbicides, the highest broad-leaved weed control efficiency (96.2 and 100% during 2016-17 and 83.9 and 98.0% during 2017-18, respectively) with the lowest weed index (6.0 and 7.0% during 2016-17 and 2017-18, respectively) was achieved with metsulfuron + carfentrazone + surfactant treatment during both the years of experiment.

Weed free treatment recorded significantly higher grain yield (5.33 and 5.44 t/ha during 2016-17 and 2017-18, respectively) in 1st and 2nd year of experimentation. This was followed by metsulfuron + carfentrazone + surfactant treated plots (5.01 and 5.06 t/ha during 2016-17 and 2017-18, respectively), the best performed treatments among various post-emergence herbicides combination used in the experiment. There was no significant difference in yield achieved with weed free treatments and treatments comprising of metsulfuron + carfentrazone + surfactant. Maximum gross return, net return and benefit: cost ratio (1.83 and 1.85 during 2016-17 and 2017-18, respectively) was also achieved with metsulfuron + carfentrazone + surfactant treatment reflecting the superiority of the herbicides over other combination for controlling broad-leaved weeds in wheat.

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Weed management in maize with new molecules

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A field experiment was conducted during *Kharif* season of 2017 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Allahabad to evaluate new post-emergence herbicides (tembotrione 120 g/ha and topramezone 25.2 g/ha) with pre-emergence application of atrazine and its combination. The soil of the experimental site was sandy loam in texture, neutral in reaction (pH 7.3), low in organic carbon (0.53%) as well as with low available N (232 kg/ha), medium in available P (17.2 kg/ha) and medium in available K (315 kg/ha) contents with normal electrical conductivity (0.32 dS/m). The experiment consisted of nine treatments laid out in a Randomized Block Design (RBD) and replicated thrice. The treatments comprised of comprising of atrazine 1.0 and 1.5 kg/ha as pre-emergence, tembotrione 120 g and topramezone 25.2 g/ha as post-emergence and combination of atrazine 1.0 kg/ha with tembotrione 120 g/ha or topramezone at 25.2 g/ha or hand weeding at 40 days after sowing (DAS), hand weeding at 20 and 40 DAS and control. The recommended dose of fertilizers was 120 kg nitrogen, 60 kg phosphorus and 60 kg potash per hectare. Maize variety 'P-3401' was sown at a spacing of 60 x 20 cm. Observations on weed density and dry matter accumulation were recorded by using a quadrate of 0.5 x 0.5 m. The experimental field was infested with *Parthenium hysterophorus*, *Commelina benghalensis*, *Euphorbia hirta*, *Digera arvensis*, *Trianthema protulacastrum*, *Phyllanthus niruri* among the broad-leaved weeds, *Cynodon dactylon*, *Digitaria sanguinalis*, *Dactyloctenium aegyptium*, *Echinochloa colona*, *Eleusine indica* among the grasses and the perennial sedge *Cyperus rotundus*. Observations on various pre- and post-harvest parameters on crop and weeds *viz*., plant height, plant dry weight (crop growth rate and relative growth rate), weed density weed dry weight, and weed control efficiency was tabulated. Among the post-harvest observations, number of cobs/plant, grains/cob, seed index, grain yield, harvest index and weed index were calculated. On economics, cost of cultivation, gross return, net return and benefit cost ratio were also calculated.Weed control through various means significantly reduced the weed density over weedy check throughout the crop growth stages. The study revealed that pre-emergence application of atrazine 1.0 kg/ha in combination with post-emergence application of tembotrione 120 g/ha recorded lowest weed density and dry weight, maximum plant dry weight and highest crop growth rate. This treatment was found to be statistically significant as compared to rest of the treatments in reducing weed population and weed dry weight. It also recorded higher no. of cobs/plant, highest seed index, grain yield, harvest index, gross return, net return and benefit cost ratio. It is concluded that pre-emergence application of atrazine 1.0 kg/ha *fb* post-emergence application of tembotrione 120 g/ha recorded maximum wed control efficiency and obtained higher grain yield.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Effect of new molecule penoxsulam herbicide for weed control in transplanted rice

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Weed is such an undesirable plant grown in association with crop which snatches major part of nutrients, water, light, place and CO_2 available to the crop. Due to tough competition, crop suffers adversely and the production is reduced. Field experiments were laid out during rainy seasons (2014 and 2015) at wet land farm of Tamil Nadu Agricultural University in Coimbatore, located at western zone of Tamil Nadu. The geographical location of the experiment site is 11°N latitude and 77°E longitude with an altitude of 426.7 m above the MSL. The soil experimental site was well drained clay loam soil in texture (44.5% clay, 10.2% silt and 45.7% sand) with low available nitrogen, medium in available phosphorus and high in available potassium. The soil analyzed 234, 15.8 and 467 kg/ha of $KMnO_4$-N, Olsens' P and NH_4OAc-K, respectively with EC of 0.29 ds/m^1, pH of 8.58 and organic carbon of 0.58%. The experiment were laid out in randomized complete block design (RBD) with nine treatments and replicated thrice. The gross plot and net plot size adopted was 20.00 m^2 (5 x 4 m) and 20.00 m^2 (5 x 4 m). Short duration rice variety ADT 43 maturing in 100-110 days suitable for cultivation in Tamil Nadu was used for the study. Treatments consisted of pre-emergence application of penoxsulam, [new formulation of penoxsulam (21.7% SC by Crystal Crop Production Private Ltd)] at penoxsulam 20 g/ha, penoxsulam 22.5 g/ha, penoxsulam 25 g/ha, penoxsulam 27.5 g/ha, penoxsulam 50 g/ha, standard check butachlor 1 kg/ha, standard check pretilachlor 750 g/ha, hand weeding and unweeded check. The herbicide were applied as pre-emergence at third day after spraying followed by a hand weeding on 30 days after transplanting (DAT). Hand operated knapsack sprayer fitted with a flat-fan type nozzle (WFN 40) was used for spraying the herbicide adopting a spray volume of 500 litre/ha. The recommended dose of 130:40:40 kg NPK/ha in the form of urea, single super phosphate and muriate of potash were applied to all plots uniformly in lines and fifty percent of nitrogen was applied as basal while, the remaining dose was top dressed in tillering and panicle initiation in equal split during the course experiments. The crop was harvested on first week of October during both the years. Total weed density, total weed dry weight and weed control efficiency were recorded at 15, 30 and 45 DAT and grain yield recorded at harvest stage. The results revealed that the application of penoxsulam (21.7% SC) at 22.5 g/ha as pre-emergence herbicide can keep the weed density, weed dry weight and weed control efficiency below the economic threshold level and increase the grain yield of rice.

Effect of new post-emergence herbicide-tembotrione for weed control in maize under irrigated conditions of Himachal Pradesh

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The field experiment was conducted during 2014 and 2015 at Palampur to study the effect of tembotrione in controlling weeds in maize under irrigated conditions of Himachal Pradesh. The soil of the test site was silty clay loam in texture, acidic in reaction, high in organic carbon and P, medium in K and low in N. Sixteen weed control treatments comprising 3 doses of tembotrione (110, 120 and 130 g/ha) alone and with surfactant (isoxadifen-ethyl, 1000 ml/ha) at 2 and 3 weeks after sowing (WAS) along with farmer's practice, atrazine 1.5 kg/ha, weed free and weedy check in maize during *Kharif* each year as main factors were tested in randomized block design with three replications. *Echinochloa colona* and *Commelina benghalensis* were the major weeds constituting 25.7 and 23.2%, respectively of the total weed flora in maize during *Kharif* season. This was followed by *Ageratum conyzoides* (13.7%), *Cyperus iria* (15.1%), *Aeschynomene indica* (9.4%) and *Galinsoga parviflora* (8.0%) and other weeds (5%). Among treatments applied in maize, post-emergence application of tembotrione 130 g/ha along with surfactant at 21 DAS (Days after sowing) was as effective as weed free to control the grassy as well as non-grassy weeds. Tembotrione 130 g/ha with surfactant at 21 DAS resulted in lowest weed index (5.4, 4.7%) and highest weed control efficiency (83.9, 82.0%) during both the years. Significantly lowest N, P and K uptake by weeds were obtained with weed free followed by tembotrione 130 g/ha + surfactant at 21 DAS during both the years.

Dehydrogenase activity in soil decreased for applied herbicide concentrations from 20 to 60 DAS. However, at later stages of the crop growth (60, 80 and 100 DAS), there was a drastic increase in the activity of dehydrogenase enzyme in all the treatments. CGR and RGR were significantly higher in tembotrione 130 g/ha at 21 DAS as compared to other treatments. Weed free being at par with tembotrione 130 g/ha + surfactant at 21 DAS resulted in significantly higher N, P and K uptake by maize crop during both the years. Tembotrione 130 g/ha with surfactant at 14 and 21 DAS was comparable to weed free in increasing yield attributes and grain and stover yield of maize during both the years. Addition of surfactant (1000 ml/ha) significantly increased the grain yield and reduced the density of weeds effectively as compared to the application of tembotrione without surfactant.

Bioefficacy of new post-emergence herbicide mixture BAS 835 UBH in soybean

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The present investigation entitled "Bioefficacy of new post emergence herbicide mixture BAS 835 UBH in soybean [*Glycine max* (L.) Merrill]" was carried out during *Kharif* season of 2016 at Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, with the objective to find out suitable weed management practices for growing soybean under the agro-climatic condition of Chhattisgarh plain. The soil of experimental field was clayey in texture, low in nitrogen, medium in phosphorus and high in potassium contents with neutral pH. The experiment was laid in randomized block design having the combination of nine different herbicide treatments replicated thrice. The soybean variety '*JS 97-52*' was grown as test crop.The results of the experiment indicated that the growth characters like plant height, number of branches, number and dry weight of nodules, leaf area index, dry matter accumulation, number of pods/ plant, number of seeds/pod, seed yield (2.29 t/ha) and stover yield were increased with hand weeding twice at 20 and 40 DAS and comparable with herbicide application of imazethapyr at 100 g/ha (2.22 t/ha) and imazamox at 42 g/ha (2.14 t/ha). The herbicide mixture treatments BAS 835UBH (imazethapyr 23 g/L + imazamox 23 g/L + bentazone 460 g/L) at 800 g/ha was found superior to rest of the mixture treatment. In the experiment field, the major weeds were *Echinochloa colonum, Cynodon dactylon, Alternanthera sessilis, Euphorbia geniculata, Phyllanthus niruri, Digitaria sanguinalis, Cyperus rotundus, Commelina benghalensis* and some other weeds were dominat and observed the crop growth period. As regard to weed management practices, lowest density and dry matter of weeds and higher weed control efficiency were recorded under hand weeding twice closely followed by imazethapyr at 100 g/ha, imazamox at 42 g/ha and herbicide mixture applied treatment, BAS 835UBH (imazethapyr 23 g/L + imazamox 23 g/L + bentazone 460 g/L) at 800 g/ha. The minimum weed growth rate was recorded under hand weeding twice, which was followed by imazethapyr at 100 g/ha, imazamox at 42 g/ha.

Net returns (` 45,741=/ha) and B:C ratio (2.01) were maximum under imazethapyr at 100 g/ha, followed by imazamox at 42 g/ha, and hand weeding twice at 20 and 40 DAS. The herbicide mixture applied treatment, BAS 835UBH (imazethapyr 23 g/L + imazamox 23 g/L + bentazone 460 g/L) at 800 g/ha, generated highest net returns and B:C ratio among the herbicide mixture treatments. The lowest net returns and B:C ratio was observed under untreated check.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Bioefficacy of new herbicide molecules on weed growth and yield of blackgram

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Blckgram (*Vigna mungo*) is one of the most important pulse crop among chickpea, pigeonpea and greengram. Being a pulse crop it has great potentiality of fitting in multiple cropping system. Weed offer severe competition to this crop during early stage of growth and reduce the yield of blackgram to the extent of 75 per cent and sometimes leads to the total failure of crop (Rao 2008). The initial 4 to 5 weeks are considered to be crucial for weed crop competition in blackgram (Patel *et al.* 2011). The magnitude of losses largely depends upon the composition of weed flora, period of weeds crop competition and its intensity. But manual weeding is labour intensive and tedious and does not ensure weed removal at critical stage of crop weed competition. With the increase in labour cost and constraints in availability on time, manual weed control is no more economical practice for most of the agricultural crops. Availability of new low-dose high-potency molecules of herbicides helps in vercoming the problem of weeds at critical stage. Keeping this in view, the present research work was carried out during *Kharif*, 2016 and 2017 at the Main Agricultural Research Station, Raichur, Raichur District (North eastern dry zone of Karnataka) and at Agricultural Research Station, Bidar, Bidar District (North eastern transitional zone of Karnataka) with the objective to evaluate the bioefficacy of new herbicide molecules on weed growth and yield of blackgram (*Vigna mungo*).

Ten treatments consisting of combination of pre- and post-emergence herbicides and one intercultivation and one HW at 20 and 40 DAS. were replicated thrice in a randomised complete block design using blackgram Cv DU-1 which was sown at a common spacing of 30 x 10 cm with a fertilizer level of 25 kg N and 50 kg P_2O_5 / ha which was applied at the time of sowing. Data on weed growth, yield performance and economics was recorded.

The results indicated that at 40 DAS, at both the locations of Raichur and Bidar, significantly the lowest total weed density dry weed biomass and higher grain and stover yield were noticed with one intercultivation and one hand weeding at 20 and 40 DAS. The next best treatment was application of ready mix combination of imazethapyr + imazamox 70 WDG at 75 g/ha applied at 3-4 leaf stage of weed very effectively control the weeds apart from recording higher grain and benefit cost ratio. Ready mix combination of imazethapyr + pendimethalin (RM) 32 EC 1000 g/ha applied at 0-3 DAS was found to be the next best option of weed management in blackgram.

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A nano-based green approach for early blight disease in *Solanum lycopersicum*

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Tomato (*Solanum lycopersicum* Mill.) is one of the important vegetable crops grown worldwide, greatly affected by Early blight, caused by *Alternaria solani*. It decreases the productivity of tomato by 80%. There are several practices are present in market to overcome this deadly disease such as resistant varieties, chemical fungicide application but due to emergence of resistant pathogens have restricted the use of traditional methods. The *in-vitro* and *in-vivo* investigation for significant inhibition of pathogenic fungi *Alternaria solani,* causing early blight disease in tomato was done. Silver nanoparticles are known for their antifungal role since a long time, but their uses to control phytopathogens in field conditions has been restricted owing to dearth of knowledge regarding their effect on plant system and native soil microflora. Spherical silver nanoparticles (2–5 nm) were synthesized from cell free extract of *Trichoderma viride* (MTCC 5661) used and also observed the impact of said nanoparticles on native microflora during tripartite interaction. Foliar application of biogenic silver nanoparticles (5ìg/mL) on *A. solani* affected tomato plants resulted in significant enhancement in fresh weight (32.58%) and chlorophyll content (23.52%) than *A. solani* affected plants. The direct killing of pathogens, increased photosynthetic efficiencies, increased plant resistance and decrease in stress parameters and stress enzymes are the mechanisms employed by plants and nanoparticles simultaneously to combat the biotic stress. After treatment of infected tomato plants with biogenic silver nanoparticles, The decrease in fungal spore count, lipid peroxidation, proline content and superoxide dismutase was 48.57, 30.00, 39.59, and 28.57%, respectively as compared to infected plants. Negligible variation was observed in terms of soil pH, cultured population, carbon utilization pattern and respective soil enzymes including dehydrogenase, urease, proteinase and â-glucosidase. The study clearly depicted the anti-pathogenic role of SNP without hampering the native soil microbial diversity. The particles used in this investigation possess higher antimicrobial activities as compared to their chemical counterparts because of surface coating of secondary metabolites of *T. viride* and their precise shape and size (spherical, 2–5 nm) and has potential to revolutionize plant disease management.

Utilization of seaweed extract as bio-regulator for enhancement of morpho-physiological, biochemical traits and yield of blackgram

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A field experiment was conducted during the *Kharif* season 2012-13 at the Research farm of Department of Agronomy, Dr. PDKV, Akola, (MS). Utilization of Seaweed Extract as Bio-Regulator for Enhancement of Morpho-Physiological, Biochemical traits and Yield of Blackgram. Treatments imposed on blackgram crop consisted of six combinations of seaweed liquid fertilizer and one control, namely FS_0: Control, FS_1: K-sap at 5% + RDF, FS_2: K-sap at 10% + RDF, FS_3: K-sap at 15% + RDF, FS_4: G-sap at 5% + RDF, FS_5: G-sap at 10% + RDF and FS_6: G-sap at 15% + RDF. The other cultural practices were kept common, as recommended. The foliar spray was applied twice at 20 and 35 DAS with different concentrations (0, 5.0, 10.0 and 15.0% v/v) of seaweed extracts (*Kappaphycus* and *Gracilaria*). TAU-1 variety of blackgram use for study. Sowing of blackgram was done on 18^{th} June 2012. The sap of *Kappaphycus* and *Gracilaria* spp. having 100% concentration was procured from Central Salt and Marine Chemical Research Institute, Bhavnagar, Gujarat. Then it was converted in foliar application liquid by adopting serial dilution technique and finally the foliar spray of 5, 10 and 15% concentration. Two sprays of *Kappaphycus* and *Gracilaria* extract were applied; one at the 20 DAS and another at 40 DAS. Foliar applications of seaweed extract significantly enhanced the morpho-physiological, biochemical traits and yield of blackgram. Morpho-physiological parameter *viz.*, plant height, number of branches, leaf area, root length, total dry matter and specific leaf weight were highest with foliar spray of G-sap at 15% + RDF (FS_6). Biochemical traits *i.e.* The foliar application of G-sap at 15% + RDF recorded significantly higher chlorophyll a, b and total (a and b) content at flowering stage (1.529, 0.750 and 2.279, mg/g fr. wt.), fruiting stage (1.697, 0.903 and 2.600, mg/g fr. wt) and (1.217, 0.763 and 1.980, mg/g fr. wt) pod development stage over all other treatments.

The yield and yield attributing character *viz.*, number of pod per plant, pod weight per plant (g), grain yield per hectare (kg/ha) and straw yield per hectare (kg/ha) were showed significant effect with foliar spraying both sap *i.e.* K-sap and G-sap. Highest number of pod per plant (21.65) and pod weight per plant (9.23 g) recorded with foliar application of G-sap at 15%+RDF. Highest grain yield (1411 kg/ha) and straw yield (2561 kg/ha) was noticed with foliar application of G-sap at 15% + RDF. Second highest grain and straw yield observed with K-sap at 15%+RDF. Lowest grain and straw yield registered with control.

Foliar application of G-sap at 15% + RDF found best combination for enhancement of morpho-physiological, biochemical traits and yield of blackgram, in remaining treatment of concentration. The per cent in grain and straw yield was tune of 39% and 24% respectively over control treatment.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Degradation impact of world worst weed-*Cirsium arvense* and frost heaves on pastoral systems of Changthang and Nubra Regions of Leh-Ladakh

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Desertification is the process defining gradual land degradation in arid, semi-arid and dry sub-humid conditions. Processes involved in degradation are frost shattering/ heaving, erosion, vegetal degradation, salinization, human activities. Three years study was carried out at Hunder and Tangtse of Nubra and Changthang valley, respectively to assess the impact of above processes at altitudes of 3999 m and 4116 m by interviewing Nomads. The vegetative cover of grasslands was measured with and without expanding colonies of invasive weedy at fixed locations of cardinal points. In India, degradation under frost shattering/ heaving is 0.14 m ha, occuring in bigger pastures including on different landforms. Under increased resource acquisition, spreading plants have high potential to invade nutrient rich environment and soils of cold arid region pose a challenge to Nomads and farming community when soils freeze. Pastoral systems consist of mainly abundant growth of native species as *Kobresia* spp (dominant Cyperaceae endemic, with *Carex, Leontopodium pusillum* and *Astragalus strictus*. *Triglochin* spp., *Puccinellia* spp. *Glaux maritime*, including mostly tiny rosette species. The open humic soil is colonized by rosettes. Although due to the remoteness of Eastern Ladakh (Changthang and Nubra regions), these local flora are little affected by exotic invasions. But recently it has been observed that world's worst invasive weed - *Cirsium arvense* has the potential to with stand in harsh climate of cold Arid Region where it has started invading grassland systems and taking over even on established frost heaves areas for its establishment and further spreads even at the height of 4000 amsl under wet and semi-wet conditions of Changtnag and Nubra regions. Recorded *Cirsium arvense* has been reducing the local vegetation by more than 60 per cent due to its allelopathic effect on frost heaves and saline based heaves, and exploiting nutrients effectively. As a result, native vegetation are at the edge of disappearing fast and infested frost heaves desiccate fast, and degraded making unfit for its further expansion with native vegetation. Biomass of native vegetation under healthy frost heaves range from 0.212-0.628 kg/m^2 (51-69 plants/m^2), while desiccated heaves produce biomass nearly 0.050 kg/m^2). It has also been observed in last three years that this invasive species is expanding its colony at the rate of 35 to 190 sq m area every year as recorded during 2016 (101.03 and 325.54 m^2 in 2 colonies) and 2017 (136.86 and 515.77 m^2, respectively) in Tangste grassland. Almost all the pastures are under serious threats due to frost heaving as well as due to invasion of world worst weed-*Cirsium arvense.* At last, desiccated frost heaves are invaded by this weed. Nomads (Ms Tsewang Dolkar) with large herds visiting regularly grasslands, report that these flocks feed on tender leaves of *Cirsium*. This might be the reason of its fast spread to new areas. Due to fast declining of grass cover (shrinking pastures) with increased feeding pressure/ demand, she has to procure an additional fodder worth ` 15000-20000 under poor resources. Survey also confirms the fact that appearance of *Carex* species indicates the disappearance of native pasture grasses.

Management of *Lantana*, an invasive alien weed, in tiger reserve ecosystem of India

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Lantana is one of the world's worst weeds of South American origin that threatens native biodiversity of forest ecosystems across India. It was introduced into India as a garden ornamental and or a bio hedge plant in the early part of the 19th century and now it has virtually invaded all the tropical and subtropical regions of India. Although attempts have been made to control *Lantana* by physical, chemical and biological methods, there is no success either in its control or the prevention of its spread. No effective management strategy is yet available for the containment of this obnoxious alien weed. On the basis of critical assessment of the biological and ecological attributes of *Lantana* that enabled it to overcome all the existing management practices, we have developed a new management strategy. The new strategy involves (i) its removal by cut rootstock method, (ii) weeding of saplings from beneath the trees used for perching by generalist birds that disperse the seeds throughout their home range and from surface drainage channels originating from the area covered by such trees and (iii) ecological restoration of weed-free landscapes, preferably to the grass-land, or forest communities according to the needs of stakeholders to prevent reinvasion of the same species or secondary invasion by another alien species. The new strategy developed has been implemented successfully in demonstration plots of 2–5 hectares at the Corbett Tiger Reserve (Uttarakhand), Kalesar National Park (Haryana) and Satpura Tiger Reserve (Madhya Pradesh). The advantages of the new management strategy over other control methods currently used are: (i) cost effectiveness, (ii) simple and easy to adopt and (iii) ensures successful control of *Lantana* with-out using chemicals and exotic biological control agents, and with minimum disturbance of soil. In conservation of biodiversity in the form of National Parks, Wildlife Sanctuaries and Project Tiger Reserves, all of which constitute the protected area net-work, is the most effective conservation strategy for bio-diversity. The critical issue facing the managers of protected areas and conservationists is how to maintain biodiversity in the face of natural- and man-made perturbations in the habitat. Biological invasions – one of the anthropogenic ally mediated ecological perturbations – are threatening native biodiversity, preventing natural eco-logical succession and changing the community structure and composition, besides impacting ecosystem services. In fact, the Convention on Biological Diversity (CBD) recognizes biological invasions as the second most important causal factor for the loss of biological diversity in natural ecosystems across the world, and thus the management of invasive alien weeds in forest ecosystems is critical for the conservation of biological diversity. In most countries, biological invasions are represented by the alien species introduced accidentally or purposefully outside their native geographical distribution ranges. For example, within 50 years of introduction in India, *Parthenium hysterophorus*, an invasive weed of North American origin, invaded 14.25 million hectares of farm land alone. Similarly, *Prosopis juliflora* invaded 1.8% of the total land area4 of India. The world's top 100 invasive species include *Lantana camara*, *Parthenium hysterophorus*, *Mikania* and *Chromolaena*.

Theme 12

Miscellaneous

Enriched composting of agricultural wastes - A comparative study

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Weeds cause economic losses by competing with crop plants for nutrients, water and space resulting in 33% reduction in crop yields. Due to dynamic nature of weeds, necessary management strategies must be developed for alleviating their adverse effects on agricultural productivity and environmental health. Though poultry manure contains nitrogen 3%, phosphrus 0.3%, potassium 1.7%, calcium 2.3%, magnesium 0.6%, direct application to agricultural land causes emission of injurious gases like ammonia, methane which are toxic to human being. Nitrogen mineralization from composted poultry manure applied to soils is lower compared to non composted one. In Dairy Industry, disposal of uneaten feeds consisting of grasses, hay *etc* causes problem in storage. Weeds can be converted to compost but bulky nature and low nutrient content of them causes problems related to handling, storage and transportation. Traditional thermophilic composting is a time consuming process (3-8) months and enhancing the temperature up to 70^{o}C may kill beneficial organisms during composting. In rapid composting methods, a fertilizer supplement is being added to hasten the composting in order to enhance nutrient content. Organic farming is the need of the hour in the present day context of serious threat to our ecology and environment. As per norms in organic farming, enriched compost lacking synthetic fertilizers are required to reduce pollution. Hence a study was conducted at ICAR-Indian Institute of Spices Research to develop a rapid enriched composting technique using organic waste materials (grasses with dairy waste) for organic cultivation. A combination of jeevamrutham/TNAU bio-mineraliser/EM solution/cowdung slurry in combination with rock phosphate and poultry manure as nutrient source was added to the substrate (weeds & grasses with dairy waste). Same substrates without any nutrient source served as control.

The enriched compost produced with Jeevamrutham and rock phosphate or poultry manure contained 0.53 to 0.69% N, 0.67 to 2.5% P, 0.25 to 0.44% K, 2% Ca, 0.29% to 0.38% Mg along with micro nutrients which was nutritive than farm yard manure (FYM) that contains 0.5% N, 0.25% P and 0.3% K. The maturity period of the enriched compost was 60 days and C:N ratio was 11 to 15. Higher bacterial count was found in composting with jeevamrutham along with poultry manure. Germination index of cowpea was more than 70 and the compost was free from heavy metals. Cowpea plants were raised in the field and enriched compost was given as per the treatments. No reduction in growth of cowpea plants due to application of enriched compost was noticed in the field. Maximum yield of cowpea was recorded by the treatment application of compost having jeevamrthum and poultry manure as ingredient followed by compost having jeevamrutham and rock phosphate as ingredient. It may be concluded that preparation of compost using dairy waste as substrate (grass + paddy straw), Jeevamrutham as inoculam with enrichment of rock phosphate or poultry manure is rapid, highly nutritive and ecofriendly for organic cultivation.

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Evaluation of 'Weed Manager' App developed by ICAR-Directorate of Weed Research

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Mobile application development in recent time is growing exponentially. Now adays, each and every person in this world has a smartphone in his pocket. Smartphones combining a range of functions such as media players, camera and GPS with advanced computing abilities and touch screens are enjoying ever-increasing popularity. Smartphones help us to achieve a range of tasks through something known as applications or Apps in short.

Agriculture based mobile apps and technologies help farmers in many ways such as by spreading agricultural related information to farmers. One of the benefits of such connectivity and information flow is that it helps farmers to make better decisions in their agricultural operations. On the other side, one of the main problems being faced by agriculture sector in developing countries is that crop diseases are not diagnosed timely and efficiently. Conventional methods for disease diagnosis in crops lead to less accurate and inefficient diagnosis, consequently leading to low productivity. A mobile app namely 'Weed Manager' is an intelligent approach for weed management which is capable of working over Android mobile devices for weed management. This app was developed by the ICAR–Directorate of Weed Research, Jabalpur for providing weed management related information to the farmers, Agriculture department officials, students, other stakeholders and Industry professionals. This app allows users to scout crop name and identify common dominated weeds of that particular crops with their control measures.

The performance of the App was evaluated using the data obtained from different users. Data were collected through the pre-tested questionnaire from the users who have downloaded the App. In questionnaire, specific questions were asked related to app and were sent to all users. Out of which, 156 filled proforma have been received. Questionnaire includes the opinion of users on different points *viz.* general information, working of the app, quality/reliability of information provided, satisfaction level/easiness provided in the app, *etc.* along with suggestions for improvement. Among all, most of the users (42%) were academicians and around 28% users were students who were doing their research work on weed management including some graduate students. Only 11% farmers were using App to get information on weed management. The reason for less number of farmers using the app, could be the language of the App which is English. Therefore, future efforts are towards the development/translation of App for the farmers in Hindi as well as in regional languages.

Utilization of terrestrial weed for heavy metal treatment

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Terrestrial weed as an alternative source of heavy metal treatment from polluted water bodies, thus various weedy plant have able to treated heavy metal from polluted water. Bioremediation is one of the eco-friendly and low cast processing technologies for effective management of pollutant. Sustainable agriculture under most by polluted water irrigation as well as other environmental constraints that adversely affected soil, ground water and human health. In as much as water polluted by industrial upstream is being used in crop irrigation, in which concentration of heavy metal is elevate and thereby adversely affected sustainability of agriculture. A study was conducted in two most polluted drains such as Richhai and Urdua of Jabalpur district of Madhya Pradesh. During the analysis higher concentration of heavy metal such as Manganese (Mn) and Iron (Fe) were found in polluted drain water studies. The obtained results were also compared with Food and Agriculture Organization (FAO) guidelines. So that, there is urgent need to improved water quality through bioremediation for clean and green agriculture. The another study was conducted to evaluate the terrestrial weedy plants like that *Typha latifolia, Vetiveria zizinoides* and *Acorus calamus* for rhizofiltration of heavy metals in contaminated medium. Among the weedy plants, *Typha latifolia* followed by *Vetiveria zizinoides* reduced Fe after treatment of 5 days in exposed to spiked Fe concentration. However, manganese concentration was reduced by *Vetiveria zizinoides* when exposed to spiked Mn after treatment of 5 days in exposed to spiked Mn concentration. After this, it was concluded that the terrestrial weedy plants has considerably to reduced Mn and Fe metal in contaminated water samples. Our research provided a background of biological water purification by terrestrial weedy plants for heavy metal treatment and may be recommended to use this terrestrial weeds in water purification in the near future for conserve the green ecosystem in the earth.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Handicrafts from weeds- An opportunity for rural livelihood promotion

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India has one of the most diverse and ancient traditions of handmade products, and its handicrafts industry is an important economic and cultural asset. Though India is heading for modern economy, a sizeable population still depends on indigenous modes of production, traditional skills and techniques to make a living based on handmade products. These crafts people or artisans are the backbone of the non-farm rural economy. In India, according to sources, about 200 million artisans are engaged in craft production to earn a livelihood. Crafts production represents an opportunity to provide a source of earning and employment for otherwise low skilled, home-based women, improving their status within the household.

Production of handicrafts crafts typically involves the use of locally available, natural and organic materials that have a low carbon footprint. The wasteland weeds such as Water hyacinth (*Eichhornia crassipe*), Cattail (*Typha angustata*) and Wild sugarcane (*Sachharum spontaneum)* have a potential to produce excessive biomass. The leaves, stems and inflorescence stalks of these weeds are of fibrous in nature with strength and durability. These properties coupled with its free availability make them useful for making handicrafts. The Krishi Vigyan Kendra (KVK) of ICAR-Central Tobacco Research Institute has been serving for more than two decades in imparting skill training to rural women and youth for self-employment generation. The KVK has conducted skill training to rural women in making decorative and household articles with the use of plant parts of Water hyacinth, Cat-tail and Wild sugarcane.

Water hyacinth (*Eichhornia crassipes*) is a free floating aquatic plant that thrives and reproduces on the surface of fresh waters and/or on accumulated silty mud, and represents one of the most successful colonizers. The well grown plants were collected, cleaned and the lengthy and hollow leaf petioles were used for making various household articles like office file covers, table mats, waste bins *etc.*

Cattail (*Typha angustata*) is a semi aquatic weed that grows virtually in dense groups. They can be found growing along streams, rivers, lakes and ponds. The shade dried leaves of cattail are woven together to make a rope that is strong enough and comparable to coir rope. It is commonly used for bundling the paddy straw and also for binding the thatched shelter roof. The inflorescence stalks were used for making fruit bowls and window curtains.

Wild sugarcane (*Sachharum spontaneum)* is a perennial grass, free-tillering, often with aggressive rhizomes. The inflorescence stalks were used for making flower vases and fruit baskets.

Making use of weeds for handicrafts is beneficial in terms of

1. Creating opportunity for self-employment,
2. Producing eco-friendly items for environmentally conscious consumers and
3. Harvesting for handicrafts is an indirect way of managing the invasive weeds which are otherwise a menace to ecosystem.

The rural women who were trained are earning a net income of ` 3,000-5,000/- per month. The KVK (ICAR-CTRI) has technical expertise from ALLIKA, a social enterprise, Guntur (A.P) and CAPRE Foundation, a non-profit voluntary organization, Allahabad (U.P) that provide sustainable livelihoods to low income rural and tribal household women through the production of beautifully hand-crafted lifestyle accessories made out of weeds.

Kisan Mobile Advisory Services (KMAS) - An Effective ICT Tool for weed management in Damoh

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ICT (Information Communication Technology) in agriculture, also known as *e*-agriculture, is developing and applying innovative ways to use ICTs in the rural domain, with a primary focus on agriculture. ICT in agriculture offers a wide range of solutions to some agricultural challenges. It is seen as an emerging field focusing on the enhancement of agricultural and rural development through improved information and communication processes. In this context, ICT is used as an umbrella term encompassing all information and communication technologies including devices, networks, mobiles, services and applications; these range from innovative Internet-era technologies and sensors to other pre-existing aids such as fixed telephones, televisions, radios and satellites. Kisan Mobile Sandesh (KMS) or Kisan Mobile Advisory Services (KMAS) is one among several methods of ICTs working successfully for dissemination of latest information. KMAS is best on the liner model of communication, which involve four major component of communication process *viz.* Sender, Message, Channel and Receiver, Mobile phones, Short Message Service (sms) are important tools and can be used by the KVK specialist. The extension functionary is the user of the information while farmers are implementer at field level.

This study will explore usefulness and utility of KMAS. The findings of this investigation will provide basis for planning future strategies of change in the current/existing system. Further the investigation will give an insight in to the prevailing dissemination of agricultural technology through of Kisan Mobile Advisory Service (KMAS) network. The findings of the study will facilitate to Policy makers, Academicians and Administrators to take appropriate measures to improve the functioning of KMAS. In addition to this the findings of the investigation will serve as a resource material for formulating best and quick alternative method or tool for dissemination of agricultural technologies.

Kisan Mobile Advisory Service was launched for sending information through SMS in Damoh District through Krishi Vigyan Kendra during June 2008. The content of messages were typed in Hindi language and information related to crop production, crop protection, vegetable and fruit production, spice crops, dairy farming, weather forecasting, post harvest management and other agricultural and allied related information sent to end users. In the programme the mobile numbers of farmers, Krishak Mitra and Krishak Didi (Farmers' friend), extension officials, and input dealers were registered and grouping is done as per the enterprise/activity basis for facility of filtering purpose. Till November, 2018 about 38929 numbers were registered. The usual messages are being serving twice a week and timely information/advices are communicating as per the need of the situation. From the list of farmers, 100 farmers, 40 In-service Personnel and 20 Input Dealers were selected for the study with the objective to know their preferences and utility in their field situation. Majority of the farmers opined that time specific advisories are most important followed by weed managment information. The messages on agronomic practices are most suitable followed by management of weeds are found to be most suited as per the result. Majority of the framers were conveyed the messages minimum to one another farmers in social system.

Knowledge resource gateway for weed science: Retrieval system

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Information Gateway give target oriented services for end-user, providing access to electronic resources. The study determined that, the modern era of Information and Communication Technology (ICT) is playing a very important role for disseminating information to the users within the networked setting. One in all the challenges that libraries ought to overcome is that the increased, refined and user friendly access to native and world resources through (license) agreements with different libraries or library networks as a resource-sharing activity. Knowledge or subject gateways don't exist in isolation, however they are helpful for the user they kind a part of the broader expertise of resource discovery. J-Gate is an electronic gateway to global *e*-journal literature. The J-Gate platform is fronted by a simple, intuitive, and easy-to-use interface, and also gives users complete control over search filters and provides seamless access to millions of journal articles. By allowing users to access content from a wide variety of publishers on a single platform, J-Gate exponentially increases journal usage.

Consortium for *e*-Resources in Agriculture (popularly known as J-Gate@CeRA) is an e-Consortium of Agricultural Libraries under the Indian Council of Agricultural Research for National Agricultural Research and Education System (NARES) Libraries. Established in November 2007, the Consortium for e-Resources in Agriculture (CeRA) is the first of its kind for facilitating 24x7 online access of selected journals in agricultural and allied sciences to all researchers, teachers and students, policy makers, administrators and extension specialists in NARS through IP authentication. There are 152 Consortium members consist of ICAR Institutes/ NRCs/Directorate/Project Directorates/National Bureaux and State Agricultural Universities. CeRA is now the most sought after online platform by scientists/ teachers in NARS for literature search for their professional pursuit. To put it in a nutshell, CeRA acts like a catalyst to enhance agricultural research, education and extension activities of NARS institution in achieving excellence and setting high standards in output and service to the society.

J-Gate@CeRA can be accessed via i) Quick search: it is used to search articles or journals against the search term entered in all the fields, ii) Advanced search: It gives more searching options and is specially designed to guide you in creating a useful search, iii) Browse Journals: This helps in browsing journals (via Title, subject Publisher name). For example end user search the word weed management, it search or filtered result from the databank, the result contains various Journals, each journals has abstract and the content is available in full text form or as pdf file.

All India coordinated research project on weed management an overview

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AICRP on Weed Management is to conduct location-specific research for developing appropriate weeds management technologies and to demonstrate the weed management technologies through on-farm adaptive trials. Besides this, it is also responsible for survey and surveillance of weed flora, mapping their distribution, ecology and habitat and to conduct parallel research to evaluate new herbicides and working out the residual effect on non-targeted organisms. The overall objective of AICRP on Weed Management is to transfer weed management technologies on farmers' fields through OFT and FLDs their impact assessment and training. AICRP on Weed Management also conducts studies on biological aspect and control of problem weeds including aquatic and parasitic weeds. It also deals with to standardize techniques for herbicide residues in soil, water and food chain.

Weeds are present everywhere in cropped lands, non-cropped lands, aquatic situations, city dwellings, and concern not only the farmers but virtually every citizen of the country and are limiting crop production, and degrade quality of produce besides raising cost of production. Of the total losses caused by the agricultural pests, weeds alone contribute to as high as 37% loss in productivity. The composition and competition by weeds is dynamic, and is dependent on the soil, climate, cropping and management factors. This is due to a variety of factors, such as changing cropping practices, input-intensive cropping systems, changing climate and more aggressive crop-weed associations, development of herbicide resistance in weeds and emergence of new biotypes, invasion by alien weeds due to globalization *etc.* Some of the weed species have assumed serious proportions in many ecosystems, threatening not only agricultural productivity but also biodiversity, human and animal health. Accordingly, weed management strategies require continuous refinement and up gradation in order to meet the emerging challenges.

Systematic research work on weed management in the country started with the launching of All India Coordinated Research Project on Weed Control by the ICAR in collaboration with the United States Department of Agriculture (USDA) at six locations, *viz.* Punjab Agricultural University, Ludhiana; University of Agricultural Sciences, Bangalore; Indian Institute of Technology, Kharagpur; Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur; Govind Ballabh Pant University of Agriculture and Technology, Pantnagar; and Himachal Pradesh Krishi Vishwa Vidyalaya, Palampur. The project came into operation in April, 1978 with the financial outlay of Rs 42.97 lakhs for five years. The tenure of the project was, however, extended for one more year till March, 1984 with the savings. Further work was continued at these centres with the AP Cess fund of ICAR till the implementation of VII Plan in April, 1986.

The coordinating unit of the project was located initially at Central Rice Research Institute, Cuttack, and shifted to National Research Centre for Weed Science in 1989.

Weed management technologies in rice, wheat, maize, soybean, mustard, cotton, sugarcane, onion, brinjal, marigold have been developed. As of now total 28 workshops/group meetings/ARM in respect of AICRP on Weed Management have been conducted. Since 1989-90, 967 research papers, 61 handouts/leaflets and 176 bulletins have been published. Total 500 students under post graduate and doctorate have been guided.

Weed education: A time to change

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The education of an agricultural student specializing in weed should be in totality. The present higher agricultural education system particularly in the subject weed science is unbendable and resistant to change. According to Tamboli and Nene 2013 higher agricultural education is seen on fast track of deterioration. The present day education system is based more on theory, less on practicals and on-farm realistic classes. The curriculum for the subject weeds science/weed management must be updated and upgraded on a regular basis. Under present circumstances there is a need to produce superior weed scientists who are able to handle the changing scenario in a better and sustainable way. The assessment of students is done by three hour long theory paper followed by practical exam consisting of experiments, spotting and viva voice. This type of system is generally based on the syllabus and course knowledge of paper setter and memory ability of the students. Prior to start of an educational year students are given syllabus containing course outline and are also prescribed course books for it, students often stick to it, memorize it and repeat its content in the theory exam. The theory paper often contain choices were out of many questions you have to do some it implies that you have an option to leave some part from the whole syllabus. Similarly in the practical exam, spotting is based on the seasonal availability of weeds, and the students have to repeat the experiments which have been done by them earlier. Viva voice is based on time factor and availability of external examiner, the time allotted to viva voice inadequate and is incapable of judging the practical knowledge applicability of the students.

Emphasis is often paid in increasing the number of colleges and strength of students rather than improving the quality of graduate, postgraduate and doctoral output. Large number of students is taught by a single teacher and furthermore the full prescribed course/syllabus is also taught by a single teacher which creates hurdles in optimum dissemination of information and knowledge generation. Although different kinds of teaching aids are available but further elaboration is needed to achieve their full potential in the field of weed education. As far as weed education is concerned a blend of teacher, facilitator instructor and demonstrator is needed to develop the subject and student skills. Negligence and ignorance towards the subject will be detrimental and will create inequality from students of those Universities which have a better weed science course curriculum. Conducingly it can be said that a time has come for a change to produce competent weed teachers/scientists and this can only be possible with change in present format of weed course curriculum. Weed Science is considered a part of Agronomy but now the time has come to establish it as a separate discipline so that full potential of weeds can be exploited for use of mankind.

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Weed helps in early spread of web blight disease of mungbean caused by *Rhizoctonia solani* (Kühn)

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Mungbean [*Vigna radiata* (L.) Wilczek] also known as green gram, is one of the most valuable short duration pulse crops of India and cultivated in *Kharif* and summer seasons covering 3.43 million hectares area and production 1.71 million tonnes. Despite being an important pulse crop its productivity has been quite low probably due to various biotic and abiotic constraints. Among many biotic constraints, web blight disease of mungbean caused by *Rhizoctonia solani* Kuhn is considered as important constraints accountable for losses in production as well as productivity in India up 40 per cent grain yield depending on environmental conditions, crop stages and cultivation practices and weed density.

The collateral weed hosts play an important role in initiation and early spread of the web blight disease to the main host. Because of their proximity to the soil carrying primary inoculum and their special microclimate, the weed hosts are first to take the infection and facilitate the production of the basidiospores of the pathogen. There after the pathogen become air borne to cause leaf, stem or pod infection and produces fresh crops of basidiospores on the main host. These studies emphasize the importance of weed control, not only for reducing disease and increasing yield, but also for the potential impact on development of web blight. The present investigation it is found that 65.61 per cent reduction in web blight incidence with 39.06 per cent increase in yield in T_1 (one spray of quizolofop–p-ethyl-5 EC at 750 ml/ha at 20 DAS) followed by T_2 [hand weeding at 20 DAS (49.59 reduction in web blight incidence with 36.04% increase in yield) over control (no weeding).

Effect of different weed management practices on growth and yield of potato under organic cropping system

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The trial was conducted during *Rabi* 2017-18 in Randomized Block Design (RBD) at Research farm of College of Agriculture, Gwalior, Madhya Pradesh to find out the best weed management practice for potato under greengram-potato organic cropping system. The soil was sandy clay loam in texture, low in available nitrogen (234 kg/ha), medium in phosphorus (14 kg/ha) and potassium (240 kg/ha). The 10 treatments replicated thrice in RBD are white plastic mulch, black plastic mulch, straw mulching at 5 DAS as 5 t/ha, one hand weeding at 20 DAS + straw mulching at 25 DAS, two hand weeding at 20 and 40 DAS, one hand hoeing at 20 DAS, one hand hoeing at 20 DAS + one hand weeding at 40 DAS, recommended herbicide (metribuzin 0.5 kg/ha), recommended herbicide + one hand weeding at 40 DAS and weedy check.

Variety 'Kufri Sindoori' was used for sowing. Seed treatment was done with PSB 5 ml/kg for 30 minutes before sowing. The crop was sown on 13th November, 2017. A full dose of FYM (10 t/ha) and half dose of vermicompost 5 t/ha were applied before 15 days of sowing during field preparation. The rest half dose of vermi compost with gram flour (besan at 5 kg/ha) was applied before sowing in the field. Neem cake 250 kg/ha was applied in the soil to control termites. Foliar spray of panchagavya 3% at 10 days interval was applied 5 times in field. During first irrigation PSB + KSB + azotobacter (100 ml each/ha) was also applied to provide enzymes, vitamins and hormones to the plant. Different mulching materials were placed after five days of sowing. Metribuzin 0.5 kg/ha was sprayed at pre-emergence of crop. The crop was harvested on 26th February, 2018.

Observations for different weed spp., weed population and dry weight were recorded at 30 and 60 DAS. Crop growth parameters *i.e.* plant height, no. of leaves/plant, no. of branches/plant and no. of tubers were recorded at 30, 60 DAS and at harvest stage. While plant population/m^2, fresh weight and dry weight of tuber/plant and yield of tubers were recorded at harvest stage. Weed control efficiency was worked out at 60 DAS. Overall, it was concluded that two hand weedings at 20 and 40 DAS fetched significantly better smothering of weeds and 100% WCE with highest net returns (` 2,45,052/ha). It also gave highest tuber yield (34.75 t/ha) followed by one HW at 20 DAS + straw mulching 5 t/ha at 25 DAS. Similarly, the highest B:C Ratio of 2.39 was also recorded with application of two hand weeding at 20 and 40 DAS. The minimum net returns ` 90,388/ha were recorded with white plastic mulch with poor B:C ratio of 0.94. It was due to the high cost incurred in purchase of white and black plastic mulch which was very high resulted in poor net returns and B:C ratio.

Effect of pre-emergence herbicide on growth, yield and economics of garden pea cultivation through front line demonstration in Seoni of Madhya Pradesh

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Garden pea (*Pisum sativum* L.), is one of the important vegetable crop in India. They are rich source of minerals, vitamins, vegetable fibre and contain fair amount of carbohydrate and protein. It is grown as a winter vegetable in the plains of north India and as summer vegetable in hills. It is mainly grown for tender green pods as a fresh vegetable. This crop is infested with both grassy as well as broad-leaved weeds resulting in significant yield losses. Madhya Pradesh is leading pea growing state in India. Being nitrogen fixing legume, this crop is useful for improving soil fertility and soil conservation. In addition to meet the local demand, vegetables have the potential for distant and export market. Weed infestation in garden pea at early stage restricts the crop growth and significantly reduces the yield. Farmers are not adopting appropriate weed management practices: hence the yield of garden pea is getting adversely affected. Kymore plateau and Satpura hills of Madhya Pradesh is considered as potential area for vegetable pea cultivation but due to the lack of technical guidance and unawareness of improved technologies, farmers in this region were practicing traditional cultivars and other agronomic practices. Therefore, efforts has been made to educate the growers of four villages of Seoni district regarding the improved weed management practices of vegetable pea along with giving massive frontline demonstrations, farmers-scientists interaction and organizing field days for quicker dissemination and adoption of technologies. The front line demonstrations were conducted on farmers field of Seoni district during subsequent three seasons at four different locations under real farm situations. Prevailing farmer's practices were treated as control for comparison with recommended package *i.e.* improved weed management practice includes application of pre-emergence herbicide pendimethalin 38.7% at 1750 ml/ha followed by one hand weeding 40 DAS. The result of front line demonstration conducted by Krishi Vigyan Kendra Seoni shows a greater impact on farmers face due to significant increase in crop yield more than two fold over local check, the economics and cost benefit ratio of both control and demonstrated plot was worked out. An average of ` 60512 was recorded net profit under recommended practice while it was ` 41800 under farmers practice. Cost benefit ratio was 2.70 under demonstration, while it was 2.25 under control plots. The number of weeds per m^2 reduced in demonstrated plot by 51.36% over control. By conducting FLD of proven technologies, yield potential and net income from pea cultivation can be enhanced to a great extent with increase in the income level of the farming community.

ISWS Golden Jubilee International Conference on "*Weeds and Society: Challenges and Opportunities*", ICAR-Directorate of Weed Research, Jabalpur, India during 21-24 November 2018

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Evaluation of bio-efficacy and phytotoxicity of pyribenzoxim against weeds in rice nursery

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A field experiment was conducted to "Evaluate the bio-efficacy and phytotoxicity of herbicide pyribenzoxim against weeds spectrum in rice nursery" during *Kharif* season 2017 at Product Testing Unit, Department of Agronomy, College of Agiculture, JNKVV, Jabalpur M.P. Seven weed control treatments comprising of four doses of pyribenzoxim - 25, 30, 35 and 60 g/ha, at 10 DAS as post–emergence, bispyribac sodium at 20 g/ha at 10 DAS, oxadiargyl at 100 g/ha at 5 DAS, hand weeding and weedy check, were carried out in Randomized Block Design with three replication. The study revealed that sedge *Cyperus iria* (34.5%) was more predominant followed by grassy weeds like *Echinochloa colona* (37%) and broad-leaved weeds *Alternanthera sessilis* (23.1%) but *Commelina banghalensis* (13.9%) marked their presence in less number in rice nursery. The data further revealed that application of pyribezoxim at the lowest dose (25 g/ha) curbed the density and dry weight of aforesaid weeds appraisably. But its activity was further enhanced with corresponding increase in doses of pyribezoxim being the higher when it was applied at the rate of 35 g/ha without causing phytotxicity on rice seedlings and proved significantly superior over Bispyibac sodium 20 g/ha and oxadiargyl 100 g/ha and weedy check being at par to lower dose of pyribenzoxim at 30 g/ha. However all the herbicidal treatments did not surpass hand weeding treatment which reduce the density and dry weight of all the weeds to the maximum extent.

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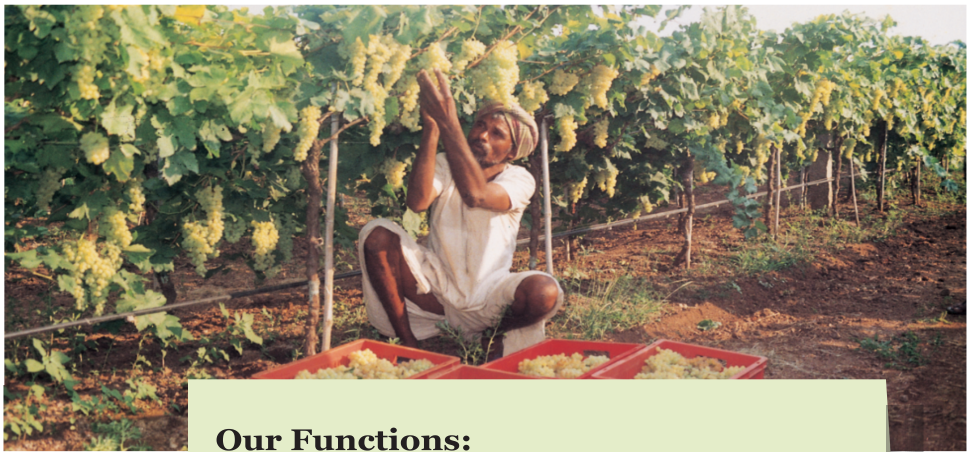

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