Indian Society of Weed Science

Biennial Conference : 2-3 November 2007

New and Emerging Issues in Weed Science

Department of Agronomy
CCS Haryana Agricultural University
Hisar, India

INDIAN SOCIETY OF WEED SCIENCE, BIENNIAL CONFERENCE ON NEW AND EMERGING ISSUES IN WEED SCIENCE

2-3 November, 2007

Department of Agronomy
CCS Haryana Agricultural University, Hisar-125 004, India

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Programe of events for ISWS biennial conference
2-3 November 2003
New and Emerging Issues in Weed Science
Chaudhury Charan Singh Haryana Agricultural University
Hisar-125004 (Haryan), India

2nd November 2007

8.30-10.00	Registration and Poster display for Session I & II (Abst. 1-66)
10.00 to 11.00	Inauguration and Award Ceremony
11.00-13.00	***Session 1 Weed Biology and Ecology***
11.00-11.25	Invasive Weeds and Global Agriculture–NT Yaduraju, N. Delhi
11.25-11.50	Weeds in Changing Climate–Effect of Alternating Rainfall- R. M. Kathiresan, Annamalai, TN
11.50-12.15	Role of Temperature and Light on Weed Growth and Herbicide Efficacy–Samunder Singh, HAU
12.15-12.50	Role of Cover Crops for Weed Management in Vegetable Crops- Robin Bellinder, Cornell, USA
12.50-13.10	Herbicides and Soil Health – Shashi Bala Singh, New Delhi
13.10-14.00	Lunch Break

14.00-19.00 Session II Direct Seeded Rice

14.00-14.05	Importance and Challenges in Direct Seeded Rice –Yashpal Shehrawat, N. Delhi
14.05-14.25	Scope of Direct Seeded Rice in India–U. S. Walia, PAU
14.25-14.45	Weed Management in Rice Under Moisture stress conditions–R. P. Singh, BHU
14.45-15.05	Weedy Rice, Biology and Management– R. K. Singh, BHU
15.05-15.30	Integrated Weed Management in Direct Seeded Rice–Samar Singh, HAU
15.30-16.00	Panel Discussion
16.00-16.30	Tea Break
16.30-17.30	Poster Session
18.00-19.00	General Body Meeting of ISWS

3rd Nov. 2007

8.00-9.00	Poster display for Sessions III, IV and V (Abst. 67-110)
9.00-12.00	Session III GM Crops, Biotechnology and Herbicide Resistance
9.00-9.40	Herbicide Resistant Crops and Glyphosate Resistant Weeds-Current Status Krishna Reddy, Stoneville, USA
9.40-10.05	Herbicide Resistant Weeds in South America – Ribas Vidal, Brazil
10.05-10.30	Struggling with Herbicide Resistance: One Step Beyond–R. DePrado, Cordoba, Spain
10.30-10.55	Importance of Herbicide Resistant Crops in India- Dheeraj Pant, Monsanto
10.55-11.20	Tea Break

11.20-13.00	***Session IV New Herbicides and Herbicide Resistance Management***
11.20-11.40	New Herbicides for Effective Weed Management–Industry's Perspective - Rajul Edoliya, Du Pont
11.40-12.00	New Herbicides for Effective Weed Management-Anil Dixit, NRCWS, Jabalpur
12.00-12.20	Current Scenario of Herbicide Resistance in Rice-Wheat System–Ashok Yadav, HAU Hisar
12.20-12.40	Problems and Management of Herbicide Resistance in India–J. N. Mazumdar, Syngenta
12.40-13.00	Non-Chemical Resistance Management Options in India–R. K. Malik, HAU Hisar
13.00-14.00	Lunch Break
14.00-16.30	***Session V Weed Ecology/Biology and Global Warming***
14.00-14.20	Strategic Weed Management Plans in Relation to Global Warming–A. K. Gogoi, Delhi
14.20-14.40	Soil Solarization and Weed Management - H. V. Nanjappa, UAS Bangalore
14.40-15.00	Direct and Residual Effect of Soil Covers on Weed Dynamics and Productivity of Cotton-Wheat cropping system-R. Sharma, Delhi
15.00-15.45	Tea Break and Poster Viewing
15.45-16.30	Panel Discussions for Posters and Presentation of Best Poster Paper Award
16.30-17.00	Closing of the Meeting

1

Invasive alien weeds in global agriculture

N T Yaduraju

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Weeds due to their intrinsic traits basically are persistent and competitive. But the absence of natural enemies in the introduced area is one of the primary reasons for some of the alien weeds assuming the status of high invasiveness. Exotic weeds form a major portion of local weed flora in several countries. A vast majority of the weeds found in India too are exotic in origin. Some weeds such as *Lantana camara* and *Eichhornia crassipes* are introduced deliberately and many more have got into the country accidentally. The most important ones being *Argemone mexicana, Acanthospermum hispidum, Salvinia molesta, Solamum elaegnifolium, Tridax procumbens,* etc. *Partheninum hysterophorus, Phalaris minor, Chromolaena odorata, Ageratum conyzoides, Mikania micrantha* and *Mimosa rubicaulis* are of recent occurrence. In the modern era, however, the problem has assumed new significance. The 'four Ts'–Trade, Transport, Travel and Tourism- which are associated with globalization, have sharply accelerated the rate of species' movements. The alien invasive weeds result in serious economic losses. One estimate suggests that annual loss by alien weeds is about US$ 336 billion in six countries including about US$117 billion for India. Invasive alien species are considered the biggest threat to biological diversity after habitat destruction. These silent green invaders constantly encroach into parks, preserves, wildlife refuges, and public amenity areas affecting native biota and eventually resulting in thousands of extinctions. The invasion by the alien plants is resulting in a shifting of species composition of many plant communities towards a preponderance of weedy, undesirable species. The loss to environment is irreversible and often underestimated. Elements for assessment need to include items such as reduction in the value of agricultural land; increase operating costs and loss in income; collapse of buildings and power failures; inefficient irrigation and lowered water tables; seed contamination, spread of disease and incremental pest control costs; loss of sport, game, endangered species and biodiversity; ecosystem disturbance and protection, monitoring and recovery costs; loss of scientific value; loss of opportunity and ecosystem services for future generations; and loss of equitable access to resources. Unfortunately the data or information on their impact on biodiversity and environment is lacking. We need to generate data on these to convince policy makers to take up this issue seriously. An estimated 8000 species of plants are believed to behave as weeds in agriculture, out of which about 250 species are considered to be potentially dangerous.

2

Weeds in changing climate

R. M. Kathiresan

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Increasing "Green house gases" and global warming is expected to trigger suppression of native bio-diversity by invasive alien weeds in India. Alteration in the precipitation and evaporation pattern coupled with frequent inundation and drought, increasing temperature regimes and sea-level rises that are regarded as consequences of global warming would alter the nature of vegetation and agriculture in India. More number of wet years (annual rainfall excess by 10% or more resulting in frequent inundation or flooding) between 1991 to 2000 compared to the preceding 10 years resulted in invasion of rice fields of Cauvery river delta in India by alien invasive weeds *Leptochloa chinensis* Nees and *Marsilea quadrifolia* (L.) by virtue of their amphibious adaptation to alternating flooded and dry situations. Increasing temperature regimes are also observed to favour invasive potential of alien weeds in India. Under upland conditions, increasing temperature above 35°C favoured the germination and establishment of *Trianthema portulacastrum* L. Germination of noxious carrot grass *Parthenium hysterophorus* L is observed to be triggered by a combination of higher temperature and moderate available soil moisture. Mean monthly maximum temperatures above 30°C linked to available soil moisture between 40 and 60% favoured the weed's germination and establishment. With increasing temperature and fluctuating precipitation, the weed may pose a severe threat assisted by globalized trade and agriculture. Similarly, the increase in root biomass of invasive alien weed *Prosopis juliflora* Swartz (DC) under increasing temperatures is observed to be higher, increasing its persistence potential and invasive behaviour.

3

Role of temperature and light on weed growth and herbicide efficacy

Samunder Singh

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There are several factors affecting herbicide efficacy; light and temperature have manifold effects. Temperature governs the translocation of herbicides in plants and also affects photosynthesis and respiration. Some herbicides are more active at higher than lower temperature, though not always as high temperature can increase volatilization of soil applied herbicides and increase drift hazards for post-applied herbicides. Higher temperature also results in increased breakdown of herbicide by soil microbes, but more than that is the effect on plant growth. Temperature has significant effect on germination, growth rate, leaf area, leaf shape, and cuticle development influences herbicide efficacy. Any change in growth or development can influence the amount of herbicide that penetrates and is retained by the plant. Similarly, light intensity directly affects herbicide penetration into the leaf through open stomata and movement of herbicide in the plant. Light stimulates weed seed germination and growth influences leaf shape, cuticle, plant height and vigour. Under high light intensity plants tend to have short internodes and many branches; low light intensity tends to produce larger, thinner leaves with thinner cuticles and less wax. These factors influence the amount of herbicide that penetrates and is retained by the plant. Effect of surfactant (spread on leaf surface and drying time) is also influenced by light and temperature. Weeds' growth varies under shade (different canopy of mature and young fruit trees), requiring differential amount of herbicides for their control. Experiments conducted under different light levels with some broad leaf weeds had different herbicide requirements. Plants growing in the open (sun) and greenhouse had differential growth and efficacy of applied herbicides. Plant height of *Sida spinosa*, *Bidens pilosa, Emilia fosbergii, Richardia brasiliensis* and *Morrenia odorata* was significantly affected by light levels (10, 30, 40, 70 and 100%) and their sensitivity to glyphosate or Krovar I (bromacil+diuron).

4

Role of cover crops for weed management in vegetable crops

R. R. Bellinder

Department of Horticulture, Cornell University, Ithaca, NY, USA

Non-harvested species, referred to as 'cover crops', 'smother crops', or 'living mulches', that are sown into a standing crop ('inter-seeded') have a number of potential benefits including supplying organic matter, improving soil quality and fertility, recycling unused soil nutrients, reducing insect-pests, and suppressing weeds. Although inter-seeded cover crops often suppress weeds, compared with unweeded controls, they also frequently cause yield reductions when compared with conventional weed management practices. Such yield losses can be due to direct competition between the cover crop and the main crop. Inter-seeded cover crops may not reduce crop yields if they are absent during the critical weed-free period. However, critical weed-free periods will vary with the vegetable crop of choice, environmental conditions, weed species and densities, and must be determined on a case by case basis. As a 'rule of thumb' establishing the cover crop just before the vegetable crop has reached 50% of its vegetative growth will, in most cases, provide maximum weed suppression with minimum competitive impact on crop yields. Cover crops may be 'managed' through time of seeding, mowing, supplying additional nitrogen to the crop at strategic times, or selective regulation with herbicides ('brown manuring'). Despite having obtained significant weed suppression with inter-seeded cover crops in potatoes, cabbage, and broccoli, research with different management strategies has shown that they cannot be the sole strategy used for weed control. They must be used in conjunction with other strategies. However, taking into account the other positive benefits of cover crops on soil health, encouraging increased use of them is important for future agricultural production. In addition to living mulches, cover crops can be sown late into vegetable crops and remain as ground cover between short season vegetables and/or regulated for subsequent no-till planting of vegetables. No-till production of cucurbits, maize and numerous transplanted vegetables has proven to be very successful and has reduced the amount of herbicides used when compared to conventional herbicide programmes. As labour costs increase and finding farm labourers becomes more difficult, finding ways to integrate weed control strategies will become essential. Using mulches and reduced tillage systems that suppress weeds, banding herbicides over crop rows, strategic cultivation, and use of low-dose; as-needed post-emergence herbicides may enable continued production without a significant increase in the cost of weed management.

5

ABA content and dormancy behaviour of some problematic weed species of winter season

Smita Bisht and S. K. Guru

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The survival and success of weeds depend on abundant seed production, rapid population establishment, seed dormancy, long-term survival of buried seeds, adaptation for spread and presence of vegetative and reproductive structures. Germination or dormancy of weed seeds from the seed bank determines the extent of seed infestation in the succeeding crops. Weed seeds differ widely in their viability. These can germinate immediately after harvest or may remain dormant for short or long periods before reviving their viability. Dormancy of weed seeds secures their long-term survival. Environmental factors such as light quality, fluctuating temperatures and chemical such as nitrates have been reported to induce or remove dormancy. Endogenous growth regulators such as GA and ABA also regulate seed dormancy and germination. In the present study, the endogenous ABA content of mature seeds of some problematic weed species of winter season was estimated by immunoassay method (ELISA). Significant variations were found in the ABA content of weed seeds with respect to their endogenous ABA content. It was reflected in the germination percentage of the species. However, in many cases endogenous concentration of ABA is not correlated with dormancy. Information on the dormancy and germination of weed species can be utilized in weed management programmes.

6

Effect of crop-weed competition on nutrient uptake patterns and bulb yield in direct seeded onion (*Allium cepa* L.)

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An experiment was conducted to investigate the effect of critical period of crop-weed competition on nutrient uptake patterns and bulb yield in direct seeded onion. The trial consisted of five weed free, five weedy treatments, laid out in randomised block design with three replications. The most critical period of crop-weed competition was between 20 to 55 days after sowing (DAS). The maximum reduction in weed dry weight was noticed in plots, which were kept weed free for initial 60 days (11.78 g/m^2) and recorded significantly lowest total weed population (60.50/m^2). The weeds that emerged after 60 DAS did not cause significant reduction in plant growth and bulb yield. The maximum number of weeds per unit area occurred between 30-45 DAS. While, higher dry matter accumulation with weeds was noticed between 45-60 DAS, maximum bulb yield (160.58 q/ha) was achieved by maintaining weed free conditions up to 60 DAS and further weed free condition did not increase the yield significantly. The increase in yield was due to favourable yield attributes like bulb diameter (4.92 cm) with higher per cent of large and medium sized bulbs as a result of higher nutrient uptake by the crop. Highest uptake of nitrogen, phosphorus and potassium by onion crop was recorded with weed free up to 75 DAS (114.37, 22.03 and 68.62 kg/ha, respectively) followed by weed free up to 60 DAS (104.26, 23.03 and 62.90 kg/ha, respectively). Uptake of nutrients by weeds decreased with increase in weed free periods. Least uptake of nutrients by weeds was noticed with weed free up to 75 DAS (1.16, 0.28 and 0.88 kg/ha, respectively) closely followed by weed free up to 60 DAS (2.33, 0.56 and 1.80 kg/ha, respectively).

7

Ageing at ambient temperature derived loss of viability and vigour in ragweed parthenium (*Parthenium hysterophorus*) seeds and implications on infestation of the weed

D. K. Pandey

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Once physiologically mature, changes accrue in the seeds with time. These may involve changes in macromolecules–proteins, lipids and nucleic acids. These changes after certain levels may manifest in changes in vigour and viability of the seeds. Ragweed parthenium is a national weed of our country with tremendous socio-economic implications mainly by way of its profound effects on agriculture, environment, and human and animal health. The weed menace may depend on seeds of the weed in soil seed bank and ageing of these seeds is one of the important factors determining number of seeds capable of emerging and forming stand over time and space as well as dynamics of viable seeds in the soil. The present investigation was undertaken to study ageing of ragweed parthenium seeds with reference to viability at ambient temperature to assess potential threat of the weed in time scale. The ragweed parthenium seeds were collected from the stands of the weed around the National Research Centre for Weed Science, Maharajpur, Jabalpur and allowed to age at ambient temperature upto seven years. The seeds were allowed to germinate in the dark at 20°C, the most suitable temperature at which most of the seeds germinate with ease and rapidity following the standard method (International Seed Testing Association, 1995). The germination was counted 16 days after initiation of imbibition. Thereafter, representative seedlings were sampled and root and shoot lengths and fresh weights were measured. The germination and seedling growth were taken as indices of viability and vigour, respectively. The results showed that majority of the seeds (>80%) of ragweed parthenium retained viability upto three years. The viability of seeds fell to 13% by four years and only 3% seeds retained germination by five years. The vigour also declined with time and was lost considerably by three years. In the seeds aged for four and five years, only a few showed radicle emergence and failed to grow further. Thus, at ambient temperature, the ragweed parthenium seeds may retain viability considerably by three years ageing but with obvious loss of vigour. The findings show importance of phytosanitation and need of destruction of seeds of the weed to prevent infestation inadvertently from sources that are likely to carry the seeds of the weed upto thee years from their physiological maturity.

8

Weed spectrum and shifts in cotton associated weeds in Punjab

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Survey of weed flora of cotton fields was conducted from 1985 to 1990 and 1992 to 1997 and thereafter, weed surveillance during 2001, 2002 and 2006 in the state of Punjab to know the weed flora composition and its shift with time in cotton fields. The data revealed that 65 weed species were found infesting cotton fields. The predominant weeds were *Eleusine aegyptiacum* (L.) Desf., *Trianthema portulacustrum* L., *Digera arvensis* Forsk., *Cyperus rotundus* L, *Digitaria ciliaris* (Retz.) Koel and *Echinochloa colona* (L.) Link. Besides these, *Eragrostis tenella* (L.) P. Beauv., *Sorghum halepense* (L.) Pers., *Physalis minima* L., *Phyllanthus niruri* L., *Celosia argentea* L. and *Corchorus tridens* L. were also important weeds of this crop. The weed survey/surveillance showed that some weeds, namely, *Cenchrus cathartichus* L. and *Tribulus terrestris* L. disappeared or were on the verge of disappearance and density of some weeds like *E. tenella* (L.) P. Beauv., *S. halepense* (L.) Pers., *P. minima* L., *P. niruri* L., *C. argentia* L. and *C. tridense* L. reduced considerably during these years may be due to improved agronomic practices. On the other hand, density of *E. colona* (L.) Link, *Convolvulus arvensis* L. and *Ipomoea pestigridis* L. were on the increase. Some new weed species like *Eragrostis diarrhena* L., *Cyperus compresus* L. and *Justicia peploids* (Nees) T. Anders were found infesting cotton fields.

9

Germination characteristics of glyphosate-resistant *Conyza canadensis* from Southern Brazil

Ribas A. Vidal[1], Juan P. Ruiz-Santaella[2], Augusto Kalsing[1], Ives C. G. R. Goulart[1], Fernando Bastida[3], Julio Menéndez[3], Hugo Cruz-Hipólito[2], Rafael de Prado[2]

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Conyza canadensis (horseweed or marestail) biotypes from southern Brazil were diagnosed as resistant to glyphosate after several years of herbicide application. This research was designed to evaluate the effect of temperature on the seed germination characteristics of one glyphosate resistant biotype. Glyphosate resistance was tested with classical dose-response curves of glyphosate applied on plants at the twelve-leaf growth stage. Glyphosate resistant biotype displayed a resistance factor of four, when compared to a susceptible biotype. At constant temperature, optimal seed germination was attained at 16.7°C. The time required for 50% of maximum seed germination was around 0.5 to 1 day, when temperatures were 25 and 20°C, respectively. Alternating temperature of 15/30 °C also provided seed germination similar to the one attained at the optimal temperature. However, alternating temperature of 10/45°C yielded poor seed germination of *C. canadensis*.

10

Introduction of quality protein maize in rainfed ecosystems of Jharkhand

A. K. Dubey, R. K. Singh, A. Dandpat, M. Pathak, G. Sharma, M. Kumar, R. Ranjan , C. Kumari and Ravi. G. Singh

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The newly carved state Jharkhand has 79.70, 38.0 and 18.04 lakh ha of total geographical area, cultivable land and net sown area, respectively. The state has largely rainfed agro-ecosystem and only 8% of net sown area (1.57 lakh ha) is irrigated. Jharklhand along with Bihar is one of the country's most food and nutritional insecure states. Around 2% of its population suffers chronic hunger and 10% experience seasonal food insecurity The Jharkhand has 1.8 lakh ha under ***kharif*** maize with the production of 2.4 lakh tonnes (2004-05). The ***kharif*** maize crop is grown in rainfed ecosystems with an average productivity of 1315 kg/ha. An effort was made to introduce Quality Protein Maize (QPM) in Koderma district of Jharkhand for its adoption with the objective of alleviating protein deficiency and promoting health especially among children and women. Farmers' participatory trials on QPM were conducted during ***kharif*** season of 2006-07 in Koderma district of Jharkhand with QPM hybrid Shaktiman-4. Crop establishment treatments : T_1-broadcasting with local variety (Tinpakhiya), T_2-planting by punch planter and two hand weedings 30 and 45 days after sowing (DAS), T_3-sowing behind plough and weed control by atrazine @ 1 kg/ha followed by one hand weeding 30 DAS were tested in 19 farmers' participatory trials. QPM hybrid produced longer plants, longer cobs, higher cob weight/cob, more grains and grain yield/cob, which resulted in higher grain yield (36.2%) more green fodder (104%) and dry fodder yields (251%) than local cultivars. Further application of atrazine @ 1 kg/ha followed by one hand weeding at 30 DAS improved the QPM grain yield (46.4%), green fodder yield (75.6%) and dry fodder yield (51.25%). Farmers were highly satisfied about the performance of Hybrid Shaktiman-4 in respect of grain yield, green fodder yield and high remunerative value of green cobs.

11

Weed seed bank development in long term herbicidal trials in rice-wheat cropping system

Neha Rawat, Anjana Bhatt and S. K. Guru

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Compositions of seed banks are influenced by cropping histories as well as farming practices. In the present study, weed seed bank was estimated in two long term herbicide trials in rice-wheat cropping system at Pantnagar. In long term trial I three monocot and seven dicot weed species were identified, while in long term trial II, three monocot and four dicot weed species were identified. *Phalaris minor* was the major weed species among monocots in both the trials, whereas *Trianthema monogyna* was the major weed species among dicot in trial I and *Melilotus* was the major weed species among dicot in trial II. The total number of seeds per m^2 was maximum in D 1 depth in both the trials.

12

Study on biology of *Mimosa invisa* and its effect on weed suppression and soil fertility improvement

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Thornless Mimosa (*Mimosa invisa)*, an introduction to Orissa from south India, is a legume which bears both single and cluster nodules on its roots where atmospheric nitrogen is fixed. Its prolific root and shoot growth can check weed growth and at the same time add organic matter to the soil. The present investigation was conducted during the year 2006-07 to study the biology of thornless Mimosa and its role in weed suppression and soil fertility. The germination percentage of fresh (2006-07 harvest) and old (2002-03 harvest) seeds was examined under laboratory conditions. Seeds were soaked in warm water for 12 h and then put on Petriplate (with wet blotting paper on its base). Seed germination at 72 h was 88% and 80 for fresh and old seeds, respectively. Field experiments were conducted under rainfed upland situation to study its establishment, growth pattern at different time intervals, phenology, nodulation behaviour, weed suppression and soil fertility build up. The crop was studied under four different treatments at seed rate of 2.5, 5.0 and 10.0 kg/ ha with light tillage and levelling after sowing and seed rate of 5.0 kg/ha without any tillage and levelling after sowing. Mimosa seeds were soaked in warm water for 12 h and incubated for another 12 h prior to sowing. There was no rainfall for 10 DAS; however, four days after rains seeds germinated and produced adequate plant stand. The phenological stages were same in all the treatments. Visible root nodules under field condition appeared at 20 days. Flowering and maturity occurred at 100 and 150 days, respectively. Growth behaviour of plants was studied at 60, 80 and 110 days after first receipt of rain after sowing in all the four treatments. The mean shoot length of plants at 60 days was 21.1 cm, which increased to 104.0 cm at 80 days and 118.2 cm at 110 days. Such rapid growth of plants from 60 days to 80 days was also seen with respect to branches/plant, average length of branches, leaves/plant, root length and fresh weight of shoot, root and nodules. Effect of Mimosa on weed suppression was studied by estimating the biomass of Mimosa and weeds 140 DAS. This was compared with biomass of weeds in plot without Mimosa (Control). Maximum weed suppression was observed when Mimosa seeds were sown @ 10 kg/ha. However, sowing of 5 kg seeds/ha may be adopted which gave similar degree of weed control as 10 kg/ha. There was much increase in soil organic carbon due to growth of Mimosa even when 2.5 kg seed/ha was used.

13

Adoption pattern of herbicide application techniques in wheat in district Kurukshetra (Haryana)

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Effectiveness of herbicides largely depends upon the herbicide application techniques like time of application, type of nozzle and quantity of water used in spraying per unit area. In order to evaluate adoption pattern of the herbicide application techniques a survey of wheat growers was conducted in district Kurukshetra (Haryana) during the year 2006-07. In this study, 77 farmers were interviewed covering 1034.5 acres of wheat. The study revealed that 41.6 and 58.4% farmers applied herbicides in wheat at 35 and 45 days after sowing (DAS). Time of application slightly influenced the grain yield resulting in 2.7% higher average grain yield if herbicides were applied at 35 DAS. The data revealed that 49.3 and 50.7% farmers used flat fan and cut nozzles for spraying in 51.5 and 48.5% area of wheat, respectively. Application of herbicide with flat fan nozzle controlled the weeds effectively resulting in higher grain yield (47.2 q/ha) than cut nozzle (43.6 q/ha). Farmers used lower quantity of water than the recommended quantity and maximum farmers (46.8%) used 300-337.5 l/ha water followed by 37.5% (375 l/ha) and 15.6% farmers (225-262.5 l/ha) for spraying of herbicides in wheat. Use of less quality of water (225-262.5 l/ha) could not control the weeds effectively and resulted in 14.7% less grain yield than the 300-375 l/ha water used in application of herbicides.

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Adoption pattern of different herbicides in wheat in district Kurukshetra (Haryana)

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Wheat is grown in 0.11 million ha in district Kurukshetra (Haryana) under rice-wheat cropping system. After the development of resistance in *Phalaris minor* against isoproturon, new herbicides viz., clodinafop-propargyl, fenoxaprop-P-ethyl, sulfosulfuron and metsulfuron-methyl were recommended to control grassy and broad leaf weeds. A survey was conducted to assess the adoption pattern of different herbicides in wheat crop in district Kurukshetra and 88 farmers covering 1086.5 acres were interviewed across the district in respect of herbicide used in wheat. Perusal of survey data indicated that clodinafop, sulfosulfuron, clodinafop followed by metsulfuron and metsulfuron alone were used by 45.5, 22.7, 25.0 and 6.8% farmers, respectively. Clodinafop alone was applied in wheat infested with grassy weeds (*P. minor*) and sulfosulfuron, clodinafop followed by metsulfuron were applied in 51.6% area of wheat sown to control the grassy as well as broad leaf weeds. Metsulfuron alone was reported to be used in 5.0% area of wheat infested with broad leaf weeds only in sugarcane-wheat cropping system. Maximum average grain yield (51.0 q/ha) was obtained in sugarcane-wheat crop rotation where the infestation of grassy weeds was negligible. The use of different herbicides as clodinafop, sulfosulfuron and clodinafop followed by metsulfuron resulted in average grain yield as 47, 46.5 and 46.7 q/ha, respectively.

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Studies on the biology of new emerging broadleaf weed *Malva neglecta* Wallr.

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Malva neglecta, a broad leaf weed, was found to germinate in a temperature range of 10-30°C in Petri dish study. Maximum seed germination was observed at 20°C. Fresh seed, one season old and two season old weed seeds under scarified and unscarified seed showed the same response. Two season old weed seeds showed higher germination percentage as compared to one season old seeds followed by fresh seeds. Unscarified seeds showed significantly lower germination in comparison to scarified seeds at all temperatures in fresh, one season and two season old weed seeds. In pot experiment, weed seedlings emergence, height of weed plants, number of branches produced per plant and dry matter accumulation by weed showed an increasing trend with increase in ponding duration during summer season. Least weed emergence and growth of weed were recorded in pots with dry soil throughout the season treatment and maximum weed emergence and growth were observed where ponding of water during summer months remained for four weeks and then pots kept as continuous moist throughout the season treatment.

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Effect of farmyard manure (FYM) on growth and development of new emerging broad leaf weed, *Malva neglecta* Wallr.

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Scarified seeds of *Malva neglecta* resulted in significantly higher weed emergence as compared to unscarified seeds within different FYM levels. Maximum weed emergence was observed in plots where 20 t/ha FYM was added, whereas least weed emergence was recorded in control plots (where no FYM was added). Weed plant height and number of branches produced per plant differed significantly between scarified and unscarified seeds at different levels of FYM. An increasing trend in these growth parameters of weed was observed with increase in levels of FYM under scarified and unscarified seeds during both the years of study. Dry matter accumulation by weed increased with increase in level of FYM added. Maximum weed dry matter accumulation of 604.1 g and 281.2 g/m^2 was observed where FYM 15 t/ha was added whereas least dry matter accumulation of 326.6 g and 150.5 g/m^2 was obtained in control plots under scarified conditions during 2004-05 and 2005-06, respectively.

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Parthenium management in wasteland ecosystem

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Field experiments were conducted during 2004-05 and 2005-06 in wasteland ecosystem with heavy infestation of *Parthenium hysterophorus* in Bairghatta Panchayat (31°53' 17 to 31°53 49 N and 76°2905 to 76°2947 E) of Thural Tehsil in Kangra District of Himachal Pradesh to study the management of *Parthenium* in wastelands. The experiment was conducted in randomized block design with four replications. The treatments consisted of six weed management practices viz., glyphosate 0.50% and 0.75%; metribuzin 0.25% and 0.50%; manual weeding by cutting and uprooting and a weedy check. Results revealed that in wasteland ecosystem metribuzin 0.25% and 0.50 and glyphosate 0.50% and 0.75% applied before flowering were as effective as manual control, but only the residual effect of metribuzin was effective to control its subsequent flushes without any phytotoxic effect on grasses and also recorded nil weight of *Parthenium* upto four months of treatments over control during both the years. Metribuzin 0.50% was effective to reduce the population of new flush of *Parthenium* emerged in Feb.-March.

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Management of *Parthenium* in grassland ecosystem

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Field experiments were conducted during 2004-05 and 2005-06 in grassland ecosystem with heavy infestation of *Parthenium hysterophorus* in Bairghatta Panchayat (31°53 17 to 31°53 49 N and 76°29 05 to 76°29 47 E) of Thural Tehsil in Kangra District of Himachal Pradesh to study the management of *Parthenium* in grassland ecosystem. The experiment was conducted in randomized block design with four replications. The treatments included six weed management practices viz., metsulfuron-methyl 0.005 and 0.01%; 2,4-D ethyl ester 0.2 and 0.3%; atrazine 0.2 and 0.3% and weedy check. Results of the study revealed that metsulfuron at 0.005 and 0.01% applied at 2-3 leaf stage effectively controlled this weed and reduced its population significantly by inhibiting emergence of its new flush. Atrazine 0.3% and 2,4- D 0.3 % applied at 2-3 leaf stage were the next best. Application of metsulfuron 0.005 and 0.01% , 2,4-D 0.2 and 0.3% and atrazine 0.2 and 0.3 % applied at 2-3 leaf stage of *Parthenium* recorded significantly higher dry herbage yield as compared to weedy check.

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Studies on weed flora and weed management practices in sugarcane in Haryana state

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This study was planned with an objective to assess the relative intensity of weeds in sugarcane and weed control practices adopted under farming situations in different parts of Haryana state. Survey was carried out in three sugar factory zones of Jind, Panipat and Sonipat during the January/February in 2001 for autumn planted crop, whereas in spring planted and ratoon sugarcane it was done in the month of April of 2001 and 2002 in sugar factory zones of Panipat and Sonipat. Random sampling on species-wise weed density was recorded from five spots of each field and weed management practices adopted by the farmers were recorded by interviewing farmers in sugarcane fields. In autumn planted sugarcane, *Phalaris minor* was most dominant weed with 70.6% relative intensity (RI) followed by *Melilotus indica* (11.6%), *Anagallis arvensis* (8.9%), *Cyperus rotundus* (3.0%) and remaining other weeds (5.9%) viz., *Chenopodium album*, *Argemone mexicana*, *Lathyrus aphaca*, *Medicago denticulata*, *Cynodon dactylon*, *Rumex dentatus*, *Coronopus didymus*, *Convolvulus arvensis*, *Asphodelus tenuifolius* and *Launea asplenifolia*. In spring planted sugarcane, *C. rotundus* was observed most dominant weed with 48.4% RI, followed by *E. colona* (16.8%), *C. dactylon* (13.1%), *M. indica* (10.2%), *Trianthema portulacastrum* (6.8%) and other weeds (4.7%). In ratoon cane, *C. rotundus* was most dominant weed with 57.8% RI, followed by *C. dactylon* (14.9%), *M. indica* (9.7%), *E. colona* (6.9%) and others (10.7%). Among the weed management practices, most of the cane growers of Haryana control weeds in sugarcane by hoeing either manually or with the help of bullock or tractor drawn implements. Use of herbicides for controlling weeds in sugarcane fields is not a general practice among the farmers. Some farmers do trash mulching for managing weeds in ratoon cane.

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Scope of direct seeded rice in India

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Rice is an important grain crop in many parts of the world as it is staple food of more than 70% of the world population. Rice-wheat is a dominating cropping system of fertile and alluvial soils of north-west India, particularly Indo-Gangetic plains. Presently rice is being grown by transplanting of 4-6 weeks old seedlings in the puddled field which is a traditional method. Puddle-transplant rice is now facing serious constraints due to non-availability of labour and rapidly escalating labour costs. Continuously puddling of fields leads to deterioration of soil properties by breaking soil aggregates and forming hard pan at plough depth, thereby yield of the following crops gets decreased. Consequently, the productivity of the rice-wheat system has stagnated. So, there is a need to develop sustainable agro-technology to increase the productivity of rice without affecting the agrosystems. Direct seeding of rice (DSR) is an alternative method of crop establishment which reduces the risk of cracking of soil under limited water supply and ensures its timely sowing in a stipulated period. DSR offers certain advantages such as lower labour costs, less drudgery, early crop maturity by 7-10 days, higher tolerance to water deficit, lower production cost and more profit and less methane emissions. As there is no need of puddling, it saves about 20% irrigation water and gives 18-20% higher water use efficiency without any significant loss in yield. Field results show that due to absence of flooding in DSR culture, weeds are the biggest constraint as all types of weeds emerge at the same time as the rice seedlings. Certain post emergence herbicides like azimsulfuron and bispyribac are very effective in controlling weeds in addition to the pre emergence application of pendimethalin. Sowing should be done before the onset of monsoon season with proper seed drill or uniform broadcasting for the successful cultivation of DSR. A seed rate of 40 kg/ha was found to be optimum. Short duration and quick growing varieties like PR-115 are most suitable for DSR. Recommended doses of nutrients to both nursery and transplanted rice should be applied to DSR. The transition to direct seeding of rice can be successful if accompanied by proper crop establishment and effective weed management practices.

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Weed management in rice under moisture stress conditions

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The available literature on weed problems and their control in upland low moisture stress rice fields in India is reviewed and suggestions for future research are included. The problem of weed competition with upland rice is of great economic importance in the country, because it causes 50-91% reduction in grain yield. Upland rice is infested with diverse types of grasses, sedges and broad leaved weeds. The initial 3-4 weeks after rice seeding have been found to be critical with respect to crop weed competition. Weed control methods that are eco-friendly to the environment and affordable to farmers must be sought. In upland rice, method of crop establishment and tillage operations had great influence on the nature of weed infestation and competitive ability of the weeds. Integration of indirect method viz., summer ploughing, stale seed bed technique, sowing of the crop, judicious nutrient management and establishment of solid and uniform row, and direct method viz., manual, mechanical, chemical and integrated method of weed management to anticipate and manage weed problems which should be socially acceptable, economically feasible and environmentally safe way are the major options of weed management on long term basis in rice under moisture stress conditions.

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Weedy rice, biology and management

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In most rice areas of South-East Asia, the spread of weedy rice became significant mainly after the shift from transplanting to direct seeding; and has become very severe after introduction of weak, semi-dwarf rice varieties. The weedy biotypes belong to the same genus and species as commercial rice. The weedy biotypes have morphological differences from the commercial varieties at the tillering and post-tillering stages with more numerous, longer and slender tillers, taller plant stature, the easy shattering and red pigmentation of pericarp. *Oryza officinalis, O. rufipogan, O. nivera* and weedy biotypes of *O. sativa* infest severely the rice field affecting yield and quality of harvest by farmers. The main weedy rice management strategies include preventive measures, augmentation of germination and control by mechanical or chemical means before seeding of the commercial rice crop and *in-crop* situation, cutting the panicle, continuous roughing, crop rotation and planting of herbicide resistant rice cultivars. The HR-rice while offering an excellent control option increases the risk of gene flow. These strategies need to apply in a holistic manner within the framework of integrated weed management system for sustainable management of weedy rice.

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Integrated weed management in direct seeded rice

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Sustainability of rice-wheat cropping system is threatened due to increasing input costs, declining water table and adverse effects of puddling on soil. Adoption of direct seeded rice (DSR) can help in reducing the production cost by escaping puddling and transplanting drudgery as well as saving water. Weeds are the major constraints for success of DSR; weed flora also differs under dry and wet DSR. Yield losses range from 10-100%, depending on the weed flora, their intensity and duration of competition. Weed problem in DSR can be tackled successfully by integrated weed management (IWM) practices. IWM mainly includes stale seed bed technique, tillage practices, use of competitive varieties like tall basmati rice, water management, mulching, mixed-cropping of *Sesbania* for brown manuring and application of suitable chemicals. The various cultural practices have been found effective in controlling the weeds by 40-60% compared to weedy check in DSR. Chemical weed control is preferred due to time and cost effectiveness. Pre-emergence application of pendimethalin at 1 kg/ha in dry DSR and pretilachlor with safener at 500 g/ha in wet DSR effectively controlled the grassy weeds for around 25 days. Pendimethalin has some adverse effect on germination of rice when it comes in direct contact with seed, whereas pretilachlor requires stagnation of water for few days for its full efficacy. Application of propanil at 1750 g/ha or fenoxaprop-ethyl at 50 g/ha or cyhalofop-p- butyl at 120 g/ha around 20 days after seeding is effective against most of the grassy weeds. Cyhalofop controls *Echinochloa colona* effectively but has only a marginal efficacy against some of the other grasses. Fenoxaprop has narrow range of selectivity. For the control of broad leaf weeds and sedges, application of metsulfuron+chlorimuron (Almix) at 4 g/ha or azimsulfuron at 25 g/ha or bensulfuron-methyl at 60 g/ha or ethoxysulfuron at 18 g/ha or trichlopyr at 500 g/ha or 2, 4-D (Ester) at 500 g/ha around 21 DAS significantly reduced the density and dry weight and were effective in producing higher grain yield of rice over weedy check. Application of herbicides followed by one hand weeding around 45 DAS was effective in reducing the complex weed flora and improving the yield. Proper application of effective and safe herbicides or their compatible mixtures at optimum dose and time are required as components of IWM in developing the weed control strategy in DSR without any adverse effects on the environment and human health. Continuous monitoring to identify the emergence of new weed species and the weeds which are difficult to control such as weedy rice is also necessary for economically viable IWM system in DSR.

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Bioefficacy and phytotoxicity of new molecule XL-COMBI-SG for weed management in tea

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A field experiment was conducted during 2007 summer (March-May) and ***kharif*** (June-August) to find out the effect of new herbicide molecule XL-COMBI SG (mixture of glyphosate ammonium salt 35% and 2,4-D sodium salt 35%) on the weed flora and to evaluate the phytotoxicity on tea plants. The experiment was carried out in a randomized design with seven treatments replicated thrice at Kamalpur Tea Estate locating at Siliguri Bagdogra area of Darjeeling district in West Bengal. The treatments comprised two doses of the standard glyphosate 41% SL viz., Glycel (5 and 10 ml/l water), four doses of XL-COMBI-SG (3, 5, 7 and 10 g/l water) and weedy check. The herbicides were applied on third week of March (summer) and June (***kharif***) with a knapsack sprayer fitted with flat jet deflector nozzle with a spray volume of 500 l/ha. The major weed flora consisted of *Axonopus compressus, Paspalum conjugatum, Paspalum distichum, Oplismenus compositus, Eleusine indica,* and *Paspalidium flavidum* among grasses and *Cyperus compressus, Cyperus mucronatus*, *Cyperus iria* and *Cyperus aromaticus* among sedges. *Oxalis corymbosa*, *Peperomia pellucida*, *Capsella bursa pastoris*, *Muehlenbeckia platyclada, Crassocephalum crepidioides*, *Acalypha indica, Scoparia dulcis, Mikania micrantha, Sida carpinifolia, Coccinea grandis, Ocimum sanctum, Ageratum conyzoides* and *Leucas linifolia* among broadleaf weeds. The maximum control of grasses, sedges and broadleaf weeds was obtained from XL-COMBI-SG 10 g/l water followed by XL-COMBI-SG 7 g/l water and glyphosate 41% SL at 10 ml/l. The gradual decrease in weed control efficiency after 45 DAT was recorded mainly due to the resurgence of perennial weeds having stolon or sucker (grasses), nut (sedges) and corm, tuber, rhizome (broadleaf). No phytotoxicity was recorded in tea plants either due to glyphosate or the new molecule XL-COMBI-SG.

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Effect of herbicides on dry seeded rice (*Oryza sativa* L.) and associated weeds

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A field experiment was conducted during the ***kharif*** season of 2002 to find out the effective dose and stage of application of cyhalofopbutyl applied at 80, 100, 120 g/ha, quinclorac at 125, 187.5, 250 g/ha, clefoxydim at 50, 75, 100 g/ha applied at 15 days after sowing (DAS) and pretilachlor at 0.5, 0.75, 1.0 kg/ha, pendimethalin at 1.0 kg/ha applied as pre-emergence to control grassy, non grassy weeds and sedges in dry seeded rice. The major weed species in the experimental field were *Echinochloa* spp., *Caesulia auxillaris*, *Ischaemum rugosum* and *Commelina diffusa*, constituting more than 85% of total weed density. Pre-emergence application of pendimethalin at 1.0 kg/ha resulted in significantly lower population of grassy weeds but showed no control of non-grassy weeds. Highest yield attributes grain yield (62.8 q/ha) was observed under weed free condition followed by pendimethalin at 1.0 kg/ha (54.0 q/ha). Cyhalofopbutyl at 120 g/ha was also found effective against annual grassy weeds and proved superior to other herbicides. Uncontrolled weeds caused 98.64% reduction in grain yield of rice.

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Effect of time and dose of post emergence herbicides on *Echinochloa* spp. control in blackgram grown as relay crop

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Field experiments were conducted during ***rabi*** seasons of 2002-03 and 2004-05 at the Regional Agricultural Research Station, Lam, Guntur, Andhra Pradesh to study the optimum time and dose of post-emergence herbicides for *Echinochloa* spp. control in blackgram grown as relay crop. Results indicated that all the post-emergence herbicides viz., fenoxaprop-P-ethyl, clodinafop propargyl and cyhalofop-butyl significantly reduced *Echinochloa* spp. growth and increased yield of blackgram ranging from 27 to 42% over weedy check without any crop injury. Among the different herbicides and their doses, fenoxaprop 68 g/ha recorded the highest seed yield (1332 kg/ha) and net monetary returns (Rs. 21,993/ha) and B : C ratio of 1.95 and was similar to its lower dose (56 g/ha). Herbicides applied at 21 and 28 days after sowing (DAS) significantly reduced *Echinochloa* spp. density recorded 20 and 40 DAT (days after treatment) and total weed dry weight compared to application at 14 DAS. However, the differences in seed yield due to time of herbicide application were not significant.

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Integrated weed management in direct sown semi-dry rice

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An integrated weed management study was conducted consecutively during ***kharif*** 2005, 2006 and 2007 at Regional Agricultural Research Station, Lam Farm, Guntur, Andhra Pradesh to evolve suitable weed management technique for direct sown semi-dry rice. Results indicated that all the integrated treatments were superior to alone application of herbicides in reducing weed growth and recorded higher yields. Pre-emergence application of pendimethalin at 1.0 kg/ha integrated with one hand weeding at 30 DAS recorded the lowest weed growth and highest grain yield (4225 kg/ha) and was similar to all other integrated treatments. Pretilachlor 750 g/ha followed by one hand weeding 30 DAS was the cheapest integrated weed management treatment (Rs. 1970) in semi-dry rice and recorded yield similar to pendimethalin at 1.0 kg/ha followed by one hand weeding.

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Integrated weed management in zero-till sown maize

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Field experiments were conducted during ***rabi*** 2005-06 and 2006-07 at the Regional Agricultural Research Station, Lam, Guntur, Andhra Pradesh to find out the most effective weed management practice in zero–till sown maize crop grown after rice. Results indicated that all the weed control treatments significantly reduced weed growth and increased maize yield ranging from 22 to 62% over weedy check without any crop injury. Pre-emergence application of atrazine 1.5 kg/ha followed by hand weeding at 30 days after sowing (DAS) recorded highest seed yield (100.1 q/ha) and net monetary returns (Rs. 48,005/ ha) and B : C ratio of 2.8 and was similar to all other integrated treatments including alone application of atrazine 1.5 kg/ha (89.5 q/ha) and also with hand weeding at 15 and 30 DAS (105.3 q/ha). Unchecked weed growth throughout the crop growing period caused 43% reduction in grain yield.

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Effect of rates of Katerina (isoproturon 50%+ metribuzin 10% WP) on wheat and associated weeds

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A field experiment was conducted during ***rabi*** seasons of 2005-06 and 2006-07 at GBPUA&T, Pantnagar to evaluate the efficacy of 'Katerina' in wheat. The treatments consisted of four rates of 'Katerina' (1500, 1750, 2000 and 2250 g/ ha), clodinafop-propargyl 400 g/ha, sulfosufuron 33.3 g/ha along with weed free and weedy check. All the treatments were replicated thrice in randomized block design. The dominant weeds were : *Phalaris minor* among grasses and *Chenopodium album, Melilotus* spp., *Medicago denticulata, Rumex acetosella* and *Coronopus didymus* among broad leaved weeds. Efficacy of 'Katerina' at 1750, 2000 and 2250 g/ha was higher than that at 1500 g/ha against weeds. Results also indicated its higher efficacy at 1750 g/ha or at higher rates than that of clodinafop and sulfosulfuron at used rates. Higher rates of 'Katerina' recorded some phytotoxic effects on the wheat crops, which recovered at later stages of crop growth. The application of 'Katerina' reduced the weed population and weed dry matter significantly. Weed competition in weedy plots caused more than 59% reduction in the grain yield of wheat. Highest grain yield was recorded under weed free condition which was similar to sulfosulfuron and 'Katerina' at 1500 and 1750 g/ha. Increased dose of 'Katerina' after 1750 g/ha reduced the grain yield but the differences were significant only between 1750 and 2250 g/ha rate. The reduction in grain yield with 'Katerina' at higher doses (2000 and 2250 g/ha) was because of reduction in number of spikes/m^2 at these rates.

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Effect of establishment methods and weed management practices in aromatic rice

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The variety Pusa Basmati-1 is popular among farmers as the yield is almost double than that of traditional Basmati rice crop. As the Pusa Basmati-1 variety has long awns, it can be easily identified from other varieties. Attempt to introduce direct sowing of this variety at farmer's field often fails owing to non competitiveness of direct seeded rice to weeds. Manual weeding becomes difficult because of possible damage to rice plants, problem in differentiating grassy weeds, labour scarcity and time consuming and relatively less effectiveness. An experiment was conducted with rice variety Pusa Basmati-1 during rainy (***kharif***) seasons of 2003 and 2004. The soil was sandy clay loam in texture low in nitrogen with 0.60% organic carbon, high in available phosphorus (50 kg/ha) and potassium (235 kg/ha), neutral in reaction (pH 7.5), and with EC 0.28 mmhos/cm. The experiment was laid out in two-factor randomized block design comprising two establishment methods (direct sowing and transplanting) and four weed management practices viz., anilofos (PRE) @ 0.4 kg/ha, butachlor (PRE) @1.5 kg /ha , two hand weedings (30 and 60 DAS) and weedy check, replicated thrice. In weedy check plots, the cost of cultivation was more than gross return which resulted in loss. The maximum gross return was recorded in direct seeded rice with two hand weeding treatments. However, higher net profit was observed in rice treated with application of anilofos @ 0.4 kg/ha.

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Integrated weed management (IWM) through brown manuring in unpuddled direct seeded rice (DSR)–a possible solution to combat aberrant behaviour of monsoon in rice cultivation

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Rice is grown as rainfed crop under transplanted condition both in summer and winter season in terai region of West Bengal. Onset of monsoon and rainfall during monsoon are gradually becoming unpredictable due to aberrant climatic behaviour leading to occurrence of drought at early part of crop season, thus, resulting in considerable delay in transplanting of seedling and young seedlings are often exposed to moisture stress condition. Direct seeding facilitates timely sowing and good production of rice if weeds are controlled effectively. In order to develop integrated weed management in DSR, concept of brown manuring was introduced as weed control measure in which *Sesbania rostrata* grown at inter row spaces of pair row rice was killed by 2,4-D at 25 days after sowing (DAS) followed by incorporation of dried *Sesbania.* Brown manuring was used in integration with herbicides like butachlor, pretilachlor, pendimethalin, benthiocarb, 2,4-D and paddy weeder. IWM comprising butachlor 1.50 kg/ha as pre-plant surface applicator + brown manuring + 2, 4-D 0.50 kg/ha as post-emergence at 40 DAS provided highest weed control efficiency of 89% at harvest with the grain yield of 3.0 t/ha significantly at par with complete weed free condition (3.14 t/ha).

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Influence of green manure intercropping and cono weeder on weed density and productivity of wet seeded rice under island ecosystem

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Transplanting consumes one third of production cost due to increased wages. Direct seeding would be a viable option to cope up with the burgeoning wages. In this backdrop, a study on the influence of cultural and mechanical weed management in direct wet seeded rice was carried out during wet season of 2005-06 at field crops experimental research farm of Central Agricultural Research Institute, Port Blair. The experiment was laid out in randomized block design (RBD) with seven treatments and three replications. The treatments were, wet seeded sole rice (manual weeding), wet seeded rice+*Sesbania aculeate* (*dhaincha*) (manual incorporation), wet seeded rice+*S. rostrata* (manual incorporation) and wet seeded sole rice (cono weeding), wet seeded rice+*S. aculeate* (cono weeder incorporation), wet seeded rice+*S. rostrata* (cono weeder incorporation) wet seeded sole rice (unweeded check). Rice+green manure inter crop treatments were imposed using the rice+dhaincha seeder developed by Tamil Nadu Agricultural University, Coimbatore. Taichung-sen-Yu variety of paddy was used for the study and recommended package of practices were adopted. Observations on total weed density, yield parameters of rice and yield were taken and economics and energetics were computed using standard methods. Intercropping *dhaincha (S. aculeate)* and *S. rostrata* led to significant reduction of total weed density (80.5/m^2 and 82.4/m^2, respectively) in wet seeded rice compared to sole rice at 20 DAS (136.2/m^2). Incorporation of green manures using cono weeder at 37 DAS led to lower total weed density at 45 DAS which was comparable with hand weeding. Weeding by cono weeder (40.4/m^2) was effective compared to hand weeding (67.2/m^2). Unweeded check registered higher total weed population (203.4/m^2) at 45 DAS compared to cono weeding and green manure intercropping. Yield parameters *viz.*, effective tillers/m^2, grain and straw yield were higher in wet seeded rice+*S. aculeate* or *S. rostrata* intercropping and incorporating it with cono weeder. Net returns and B: C ratio also registered similar trend as that of yield. Specific energy was lower under rice+*dhaincha* + cono weeder incorporation and it is higher for unweeded check. It can be concluded that combination of cultural (intercropping) and mechanical (cono weeder) weeding method is effective for bringing down the weed density thereby registering higher yield, net income and energetics. Among the two green manures, *dhaincha* can be recommended as *S. rostrata* requires acid treatment before sowing.

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Economics and quality of direct seeded onion in relation to different weed control methods

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An experiment was conducted to study the efficacy of different herbicides applied alone, integrated with one hand weeding and manual weeding at different growth stages on the bulb yield, economics and quality of onion bulbs. The experiment consisted of 16 treatments of which four were herbicidal treatments, six hand weeding treatments, four integrated weed control treatments, one weedy check and weed free check treatment. The experiment was laid out in randomized block design. Integrated weed management treatments involving pre-emergence application of herbicides viz., oxyfluorfen @ 0.09 kg/ha, pendimethalin @ 0.75 kg/ha and metolachlor @ 0.75 kg/ha in combination with one hand weeding at 45 days after sowing (DAS) resulted in significantly higher bulb yield of onion (148.91, 147.25 and 146.50 q/ha, respectively) due to maintenance of weed free condition during initial stages with pre-emergence application of herbicides and control of late emerged weeds as a result of one hand weeding at 45 DAS. The weed control efficiency was more than 95%. The weed index values ranged from 8.00 to 33.76% in integrated treatments as compared to 86% with weedy check indicating least crop-weed competition. Integrated weed control treatments except butachlor @ 0.75 kg/ha+one hand weeding 45 DAS were similar to each other and recorded maximum bulb diameter of 4.70 to 4.88 cm and large sized bulb yield ranged from 32.50 to 36.00%. Maximum net returns were obtained with the application of oxyfluorfen @ 0.09 kg/ha+one hand weeding at 45 DAS (Rs. 38368/ha) narrowly followed by metolachlor (Rs. 37300/ha) and pendimethalin (Rs. 37100/ha) each @ 0.09 kg/ha+one hand weeding at 45 DAS.

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Eco-friendly management of weeds in maize through cowpea intercropping

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Increased use of pesticides including herbicides has become a major cause of concern for environmental safety; therefore, integrated or cultural methods of weed control should be encouraged. Maize is an important crop of Punjab and being rainy season crop it gets infested with many grass and broad leaf weeds. To control these weeds, atrazine and alachlor are recommended. The residue of atrazine persists for some time in soil, therefore, use of this herbicide is not recommended under late sown maize. To reduce dependence on herbicides, non-chemical control of weeds should be preferred for quality produce and to save the environment from chemical pollution. Cowpea for fodder which is a quick growing crop and covers the ground completely was tried as an intercrop between rows of maize for exploiting its weed suppressing potential. Field experiments were conducted at Punjab Agricultural University, Ludhianan for four years from 2003 to 2006. Maize hybrid Paras and Cowpea 88 were sown as 1 : 1 and 1 : 2 row combinations. Cowpea was harvested 35 to 45 days after sowing, while harvesting cowpea, the weed plants were also removed and afterwards weeds remained suppressed. The cowpea fodder as intercrop gave 100 to 200 q/ha of additional green fodder yield. The maize yield from these treatments was at par with sole maize treated with atrazine and hand weeding. Therefore, growing of cowpea as intercrop in maize for fodder may be an eco-friendly approach for weed management in maize.

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Control of *Cynodon dactylon* with split application of glyphosate

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Cynodon dactylon is a problem perennial weed of all ***kharif*** season crops except rice. The problem of this weed is more under zero tillage system. Its regeneration potential is very high and it propagates very fast after any weeding operation. This weed propagates mainly through its subterranean rhizomes/stolons. A systemic herbicide which can kill or reduce its regeneration may prove useful. Single and split applications of glyphosate were tried for one year under field conditions at Punjab Agricultural University, Ludhiana during ***kharif*** 2006 to see their effect on its regeneration potential and were compared with paraquat, a contact herbicide. A uniform population of *C. dactylon* was created in experimental plots and after establishment was treated with glyphosate (1.0, 1.5, 0.5 fb 0.5 and 0.5 bf 0.5 bf 0.5 kg/ha) and paraquat (0.5, 0.5 fb 0.5 and 0.5 fb 0.5 fb 0.5 kg/ha). It was observed that three split applications of glyphosate 0.5 kg/ha each at 10 days interval resulted in complete mortality of its rhizome/stolon and was significantly better than single application of glyphosate 1.0 or 1.5 kg/ha. Three split applications of paraquat 0.5 kg/ha each were also significantly better than its single or two split applications.

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Studies on residue of oxyfluorfen in onion and garlic bulbs

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Oxyfluorfen (2-chloro-1-3 (ethoxy-4-nitrophenoxy)-4-trifluromethyl) has proved to be effective for the weed control in onion/garlic under Punjab conditions. The applied herbicide may persist in soil and leave residues in onion/garlic bulbs, which need to be determined for safe consumption. Oxyfluorfen (0.15, 0.225 and 0.30 kg/ha) was applied as early post-emergence (seven days after transplanting) onion nursery. In garlic, oxyfluorfen (0.25 and 0.35 kg/ha) was applied seven days after planting garlic cloves. Calibration curve for oxyfluorfen at a concentration range of 0.01 to 5.0 ppm was prepared in pure HPLC grade acetonitrile. The average recovery percentages for plant sample i.e. garlic and onion bulbs were found to be 75%. The residue estimation revealed that residue of oxyfluorfen (0.15 and 0.30 kg/ha) was not detected in onion bulbs at 15 and 30 DAS and at harvest, and was below detectable limits < 0.01 ppm. Similarly, no residue of oxyfluorfen (0.25 and 0.35 kg/ha) was detected in garlic bulbs at harvest. The study showed that the onion bulbs could be used for table purpose between 15-30 DAS and garlic at harvest stage.

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Bio-efficacy of Total 75 WG (sulfosulfuron+metsulfuron) in wheat and its residual effects on succeeding crops

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Field experiments were conducted at the experimental farm of Department of Agronomy, Punjab Agricultural University, Ludhiana during the ***rabi*** seasons of 2005-06 and 2006-07 to study the bio-efficacy of Total 75 WG (sulfosulfuron+metsulfuron) for controlling grassy and broad leaf weeds in wheat and to study its residual effects on succeeding crops. Post-emergence application of Total 75 WG (sulfosulfuron+metsulfuron) at 30 g/ha provided effective control of *Phalaris minor*, *Avena ludoviciana* and broad leaf weeds in wheat as dry matter accumulation by weeds significantly reduced compared to unweeded control. Total 75 WG readymix herbicide) was also found to be at par in its activity with the already recommended herbicide Atlantis 3.6 WDG for controlling weeds and wheat grain yield. Similarly, effective tillers, ear length and grain yield were significantly higher with the post-emergence application of Total (30-35 DAS) than unweeded control and was similar to Atlantis. On an average of two years, the post-emergence application of Total at 30 g/ha increased grain yield by 106% over unweeded control and 9% over Atlantis 3.6 WDG (Standard). Residual studies (bioassay) conducted in pots indicated that cotton, moong, mash, ricebean, muskmelon and bottlegourd could be successfully grown after the spray of this herbicide in wheat; however, maize and bajra showed stunted growth.

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Integrated weed control studies in chickpea (*Cicer arietinum*)

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Field experiments were conducted at the Research Farm of the Department of Agronomy, Punjab Agricultural University, Ludhiana for three years i. e. 2003-04, 2005-06 and 2006-07 to find out effective weed management method in chickpea. Results indicated that pre-plant application of trifluralin (Treflan 48 EC) 0.5 kg/ha followed by hand weeding and its alone application at 1.2 kg/ha as well as pre-emergence application of pendimethalin (Stomp 30 EC) 0.5 kg/ha followed by hand weeding and its alone application at 0.75 kg/ha were found very effective for controlling weeds as dry matter accumulation in these treatments was similar to the standard treatment i. e. pre-emergence application of linuron (Aflaon 50 WP) at 0.94 kg/ha and significantly less than unweeded (control) treatment. Similarly, number of branches per plant, number of pods per plant, plant weight and seed yield of chickpea under these treatments were found statistically similar to the standard treatment and all these treatments were found to be significantly superior to unweeded control. On an average of three years, pre-plant application of trifluralin 0.5 kg + one hand weeding and 1.2 kg/ha alone as well as pre-emergence application of pendimethalin 0.5 kg/ha+one hand weeding and 0.75 kg/ha alone increased yield of chickpea by 144.6, 126.8, 150.5 and 130.2% than unweeded (control) treatment, respectively.

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Bioefficacy of pinoxaden 5 EC for controlling *Phalaris minor* in wheat (*Triticum aestivum*)

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Field experiments were conducted during the ***rabi*** seasons of 2005-06 and 2006-07 at the experimental farm of the Department of Agronomy, Punjab Agricultural University, Ludhiana to study the bioefficacy of pinoxaden 5 EC for controlling *Phalaris minor* in wheat. Post-emergence application of pinoxaden applied 30-35 DAS at 45 and 50 g/ha effectively controlled *P. minor* and its dry matter was found similar to the recommended herbicide i. e. clodinafop 15 WP at 60 g/ha during the first year; however, during the second year weed dry matter was significantly reduced with the application of pinoxaden at all the levels tested as compared to clodinafop. Similarly, grain yield of wheat with pinoxaden 45 and 50 g/ha was statistically similar during first year and it was significantly more during second year as compared to post-emergence application of clodinafop. On an average of two years, application of pinoxaden at 45 and 50 g/ha increased wheat grain yield by 15.6 and 17.5% than clodinafop and 60.8 and 63.4 % than control (unweeded) treatment, respectively.

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Effect of organic and chemical sources of nutrition on weed infestation and yield in soybean-wheat system

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Growing environmental concerns and global energy crises necessitate the development of eco-friendly farming techniques. The field experiment with soybean under soybean-wheat cropping system was conducted during 2002-03 (on already in progress experiment since ***kharif*** 1996) on loamy sand in a randomized block design with four replications comprising eight treatments viz., two farming systems i.e. organic and chemical farming and four nutrient supply systems. In chemical farming system for soybean, weeds were controlled with pre-emergence application of pendimethalin 30 EC at 0.45 kg/ha, in wheat (fenoxaprop-p-ethyl 10 EC) 100 g/ha was applied 30-35 DAS with knapsack sprayer with discharge rate of 250 l/ha of water. For controlling broad leaf weeds a follow up application of 2,4-D was made at 0.5 kg/ha at maximum tillering stage. Whereas in the organic farming system for soybean, two hand hoeings (20 and 35 DAS) followed by two wheel hoeings at an interval of 10-15 days were given; for wheat one hand hoeing was given 30 DAS and later on two hoeings with wheel hoe were given at an interval of 15-20 days. In soybean-wheat system, all the organic farming treatments i. e. 10 t FYM/ha to soybean (S_{10}), 20 t FYM/ha to wheat (W_{20}), residue incorporation (RI), S_5-W_{15}-GM (green manuring of *Crotolaria juncea*)-RI, S_5-W_{15}-RI and S_5-W_{15}-R0 (residue removal) recorded significantly higher weed population as compared to the crop receiving only recommended levels of chemical fertilizers (Rec.) at all the stages. The weed dry matter was significantly higher in organic soybean 60 DAS and at maturity over chemical farming treatments, whereas in wheat the weed dry matter was significantly higher in all the organic farming treatments when recorded 30, 60 DAS and at maturity compared to alone chemical farming treatments. The highest wheat equivalent yield was obtained in S_{10}-W_{20}-RI treatment, which was followed by Rec.-GM-RI, Rec.-GM-R0 and S_5-W_{15}-GM-RI treatments and these treatments produced 14.3, 13.2, 11.3 and 8.2% higher grain yield than the crop receiving only the recommended dose of chemical fertilizers (89.57 q/ha/annum wheat equivalent yield). Similarly, pure/partial organic treatments showed higher values for productivity varying from 30.59 to 34.60 kg/day/ha as compared to 30.26 kg/ha/day in pure chemical fertilizer treatment.

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Direct seeded rice in Eastern Indo Gangetic Plains

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Experiments were conducted at the Experimental Farm of Rajendra Agricultural University, Pusa Samastipur, Bihar , during summer (***kharif***) season of 2006 with the objective of minimizing the yield gap between zero-till/reduced till direct-dry seeded rice and transplanted rice. Soils at the experimental sites were finer in texture (clay loam type) with OC 0.68-1.6%, available phosphorus (13.7-18.3 kg/ha) and available potash (126-176 kg/ha). The studies on sowing time of DSR revealed that early planting (15 June) of a long duration variety (Sawarna, 160 d) provided higher yield; however, delayed planting (June 30) of short duration variety (Prabhat, 100 d) transformed into better plant stand and higher yields. Grain yield of DSR and puddled transplanted rice were similar for same seeding dates. In a study on, performance of rice genotypes under direct seeded system, scented, short, medium and long duration genotypes were evaluated. In general, 50% flowering was hastened by 6-7 days earlier in DSR than puddled transplanted rice (PTPR). However, rice genotypes/cultivar yield is not affected by DSR and PTPR establishment systems or interactions between crop establishment and cultivars. Cultivars Sugandh-2, Sugandh-3 (scented), Pusa 834 and PNR 381 (short duration), NP 49 and Pant 10 (medium duration) seemed promising for DSR. Performance of different rice establishment systems was evaluated including DSR under zero (ZTDSR) or reduced tillage (RTDSR) or wet seeding and transplanting under puddled and un-puddled conditions for yield and recruitment behaviour of weeds. More weeds were recorded under un-puddled wet seeded rice (WSR) than DSR or puddled WSR. Puddling was helpful in reducing the weed density under transplanting or WSR, ZT DSR or RT DSR led to similar grain yield. Similarly, direct seeding under dry or wet unpuddled condition yielded at par. However, transplanting of rice under puddled conditions resulted in higher grain yield than unpuddled direct seeding. Azimsulfuron was evaluated against *C. rotundus* in zero tillage rice. It was observed that uncontrolled weeds reduced the grain yield of direct seeded rice by 43%. The application of azimsulfuron at 25 g/ha was found effective in controlling weeds particularly broad leaf and sedges. Azimsulfuron alone or in combination with MSM or hand weeding in DSR resulted in grain yield equivalent to weed free. It appeared that a combination of pre-emergence herbicide (pendimethalin) and azimsulfuron at 25 g/ha could check the weed menace in DSR. Azimsulfuron at 22.5 to 30 g/ha when applied to rice did not cause any residual toxicity to succeeding wheat crop.

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Influence of nozzle type and surfactant on drying pattern of drop deposited on weed foliage and glyphosate efficacy

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Several factors affect herbicide weed control efficiency. Nozzle size and spray pressure determine droplet size on foliage. Surfactant (Triton X 100 at 0.01%) affected spread of droplet and droplet contact with cuticle; sucrose (2%) enhanced phloem loading and long distance transport; jaggery (2%) prolonged droplet drying period as humectant, citric acid (0.01%) and ammonium sulphate (AMS) (2%) removed antagonistic effect of divalent cations (Ca^{2+}, Mg^{2+}, etc.,) on glyphosate chelating; 8-hydroxy quinoline (8HQ); inhibited stem plugging by callose enhanced vase life. With this information, experiments were conducted using adjuvants. Narrow orifice flood jet nozzle (ZENECA AN or XLP/WP/40 from Aspee) led to fine drop deposition and 50% reduction in spray volume than wider orifice nozzle (ZENECA AN or Aspee WFN 78), where 96% of sprayed volume fell within middle 25 mm of swath width using ZENECA AN 0.6 than 45% by ZENECA AN 2.4. TX200 is more effective than TX100 for enhancing glyphosate efficacy. Finer drop (2 µL) and addition of TX200 significantly reduced the droplet drying period than coarse drop (5 µL) without TX200. Jaggery (2%) significantly enhanced droplet drying period in *Oxalis latifolia* (147%), *Digitaria marginata* and *Lagasca mollis* (155%) than glyphosate alone or with TX200 or 8HQ or AMS. *Cyperus rotundus* did not respond to these adjuvants with respect to drying period. Spread of the droplet on weed foliage (except *C. rotundus*) ws significantly more with AMS, jaggery and citric acid on par with TX200 and glyphosate alone as reflected by spread area (mm^2). Cuticle having fatty acid (18 : 3) showed strong correlation between droplet spread (0.969), drying period of glyphosate with TX200 (-0.945) and total wax (-0.896).

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Effect of time and doses of common salt and 2, 4-D application on weed growth and yield of upland direct seeded rice

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A field experiment was conducted during 2003 and 2004 on sandy loam soil at Agricultural Research Farm, Nagaland University, School of Agricultural Sciences and Rural Development, Medziphema to evaluate the effect of time of application (10 and 30 days after sowing) and doses of common salt viz., 50, 100 and 150 kg/ha and 2, 4-D Na salt @ 1.5 kg/ha application on weed growth and yield of direct seeded upland rice. Application of 2,4-D @ 1.5 kg/ha applied at 10 and 30 DAS significantly reduced weed population and dry matter accumulation, and it was at par with common salt @ 150 kg/ha applied at 10 and 30 DAS. 2,4-D Na salt @1.5 kg/ha applied at 10 and 30 DAS recorded better growth, yield attributes and yield viz., plant height, number of tillers/ hill, dry matter accumulation, number of panicles/m^2, number of effective grains/ panicle and grain yield in comparison to common salt @ 50 kg/ha applied at 10 and 30 DAS. The highest benefit : cost ratio was recorded with 2, 4-D Na salt @1.5 kg/ha applied at 10 DAS (2.47) followed by common salt @ 150 kg/ha applied at 10 DAS. Early application of common salt and 2, 4-D (10 DAS) recorded more grain yield and benefit : cost ratio in comparison to late application (30 DAS) of these treatments. Common salt application was not economical in comparison to 2, 4-D application.

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Integrated weed management in rice on farmers' field

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Rice is grown in 45 million hectare annually with a production of 96 million tonnes, contributing 45% to the total food grain production of the country. Weed competition is one of the prime yield limiting biotic constraints in rice. Quality herbicides are costly and at times not available. Therefore, integrated approach of weed control may be more desirable. Field trials were conducted in 2006 at eight locations in the farmers' fields of adopted villages in Tamil Nadu. The soil was clay in texture, medium in organic carbon (0.7%) with pH 7.2. The treatment comprising farmers' practice (local weeder), two hand weedings (HW) (20 and 40 DAT), ready mix formulation of pretilachlor + 2,4-D, pretilachlor, anilofos, butachlor and weedy check. The trials were laid out in a randomized block design and replicated thrice. Twenty one days old seedlings of rice variety ADT 36 were transplanted at 12.5 x 10 cm spacing keeping two seedlings per hill. Recommended package of practices was adopted to grow the crop. The major weeds in trial plots were *Cyperus rotundus, Echinochloa crus-galli, Echinochloa colona, Leptochloa chinensis, Marsilea quadrifolia, Eclipta alba* and *Sphenoclea zeylanica.* Minimum weed population (3.1/m) and weed dry biomass (156.8 kg/ha) were recorded in HW twice (20 and 40 DAT) followed by pretilachlor+2,4-D formulation 250+250 g/ha produced significantly lower weed population (4.2/ m), weed dry weight (233.8 kg/ha). The higher weed control efficiency (80.6%) was also recorded in two HW followed by pretilachlor+2,4-D treatment (72.9%). All the weed control methods showed significant increase in yield and its attributes as compared to farmers' practice. Grain yield loss amounted to 69% due to uncontrolled weeds compared to HW. Among the herbicide treatments pretilachlor+2,4-D formulation produced significantly higher yield attributes. The lowest grain yield of rice was recorded under farmers' practice. The highest net monetary return (Rs. 5286/ha) and benefit : cost ratio (1.61) was observed under two HW followed by pretilachlor+2,4-D formulation as compared to farmers' practice.

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Integrated weed management under direct seeded rice

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Rice production systems are undergoing several changes and one of such changes is shift from transplanted rice to direct seeding. The shift from transplanted rice to direct seed of rice may aggravate weed problem. Weeds inflict major losses in upland rice culture resulting in total crop failures. No single approach i.e. either uses of herbicides or manual/mechanical weeding is convenient in containing weed menace. Hence, an integrated strategy combining all possible methods appears to be economic option. A field study was carried out during ***kharif*** 2005 and 2006 at CCS Haryana Agricultural University College of Agriculture, Kaul (Kaithal). The experiment comprised four establishment method of direct seeded rice (unpuddled, puddle, zero-tillage and reduced tillage) as main plot treatments, while seven weed control treatments viz., weedy check, weed free check, pendimethalin at 1.5 kg/ha (PE), cyhalofop-butyl at 90 g/ha (20 DAS), pretilachlor+safener at 0.5 kg/ha (PE), pendimethalin at 1.5 kg/ha (PE) supplemented with one hand weeding (HW) 30 DAS and green manuring of Sesbania *fb* 2, 4-D (at 0.5 kg/ha 30 DAS) were kept in sub-plots. The methods of planting did not significantly influence the density and dry weight of weeds. Among different herbicidal treatments, pendimethalin at 1.5 kg/ha (PE) *fb* HW 30 DAS proved most effective and significantly better than all other herbicidal treatments in reducing the density and dry weight of weeds. Application of pendimethalin or cyhalofop-butyl alone controlled *Echinochloa* spp. effectively while it failed to control *Cyperus* spp, whereas pretilachlor+safener provided excellent control of *Cyperus* spp. The planting methods did not render any significant variation in growth parameters, yield attributes and yields. The growth parameters and yield attributes were superior under weed-free treatment followed by pendimethalin supplemented with HW 30 DAS and lowest under weedy check. A reduction of 80% in grain yield was culminated by weeds in the weedy check during both the years. The grain yield of rice was maximum in the plots kept weed free throughout the crop season. Pretilachlor+safener at 0.5 kg/ha under wet seeded, whereas pendimethalin at 1.5 kg/ha (PE) under dry seeded situations provided significantly higher grain yields.

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Integrated weed management in wheat

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A field experiment on integrated weed management in wheat was conducted during winter season of 1998 -99 at Research Farm of Birsa Agricultural University, Ranchi. Results revealed that weeding at 20, 40 and 60 DAS recorded significantly lower weed density and weed dry weight/m^2. Among absolute application of herbicides, isoproturon @ 0.5 kg/ha as post-emergence (30 DAS) recorded significantly lower weed density and weed dry matter compared to pre-emergence application of pendimethalin @ 1.0 kg/ha and post-emergence application of 2,4-D @ 1.0 kg/ha (30 DAS). The weed control efficiency was more pronounced at earlier stage and continued to reduce at latter crop growth stages. Weeding thrice at 20, 40 and 60 DAS recorded maximum weed control efficiency at all stages of crop growth (89% at 35 DAS) followed by application of isoproturon at 0.5 kg/ha (85%). The lowest weed index (7.07%) was recorded due to weeding at 20 DAS + isoproturon @. 5 kg/ ha as post emergence (30 DAS) followed by one hand weeding at 20 days after sowing +2,4-D @ 0.5 kg/ha at 30 DAS (16.7%). Significantly higher wheat grain yield (35.48 q/ha) was recorded when wheat crop was hand weeded thrice at 20, 40 and 60 DAS, remaining at par with one hand weeding at 20 DAS followed by isoproturon @ 0.5 kg/ha as post-emergence at 30 DAS (32.97 q/ ha). Grain yield was in accordance with yield attributing parameters as hand weeding thrice at 20, 40 and 60 DAS produced maximum number of effective tillers (282.62/m), spike length (9.55 cm), grain/spike (40.75), 1000-grain weight (44.01 g) and was at par with one hand weeding at 20 DAS+application of isoproturon @ 0.5 kg/ha at 30 DAS.

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Weed control in fingermillet under irrigated condition

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Four herbicides viz., butachlor @ 0.75 kg ai/ha, isoproturon @ 0.5 kg/ha and oxyflurofen @ 0.1 kg/ha as pre-emergence herbicides and 2-4 D ethyl ester @ 0.75 kg/ha as post-emergence herbicide were used for the study under irrigated condition in fingermillet crop. The crop was raised in two methods i.e., drill sowing and transplanting under irrigated conditions during ***kharif*** 2001, 2002, 2003 and 2004 at Zonal Agricultural Research Station, V. C. Farm, Mandya. The statistical design used was split plot with three replications. The research results revealed that the mean grain yield was significantly superior in transplanting method of establishment (2807 kg/ha) compared to drill method of establishment (2201 kg/ha). Among the herbicides tried for weed control, oxyfluorfen applied as pre-emergence spray @ 0.1 kg/ha recorded significantly higher yield (2800 kg/ha) than other herbicides used for weed control. The weed dry weight and total weed population/m^2 was significantly lower in oxyfluorfen sprayed plots both at 30 and 60 DAS (weed dry weight of 1.70 and 4.46 and weed population of 4.51 and 6.80/m^2, respectively) compared to weedy check (weed dry weight of 5.72 and 10.54 and weed population of 12.15 and 12.76/m^2, respectively) and recommended practice of two intercultivations (weed dry weight of 2.83 and 6.39 and weed population of 6.50 and 6.80/m^2, respectively).

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Economic disparity in direct seeded *vs* transplanted rice : a case study

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Rice (*Oryza sativa*) is one of the most important staple food crops in the world. The slogan "rice is life" is most appropriate for India as this crop plays vital role in our food security and is a means of livelihood for millions of rural household. Direct seeded rice (DSR) technology has not been widely adopted in India. DSR avoids transplanting, thus reducing the labour requirement for transplanting, saves water and maintenance cost. Generally, it seems that benefits will go to large farmers who rely heavily on labour. However, the small farmers have to face several constraints to adopt the DSR technology. In view of the above fact the household survey has been conducted to study the cost and return of DSR and TPR and to examine the input use efficiency in these technologies. Regression analysis was adopted for estimation. The survey was conducted during ***kharif*** 2006 in district Udham Singh Nagar by selecting 20 DSR and 20 TPR farm households. The result showed that the differences in cost of cultivation were Rs. 2597 per acre between TPR and DSR technology. However, in DSR the average yield was 42.5 compared to 40 q/ha in TPR. The benefit : cost ratio was found 1.83 and 1.42 in DSR and TPR, respectively. Weed management was main constraint in DSR, thus herbicidal cost was more in DSR, but the cost involved in land preparation and crop establishment was more in TPR as compared to DSR. The production elasticity of herbicide and fungicide shows that 1% increase in the use of herbicide and fungicide is expected to increase the productivity of paddy by 0.0092 and 0.0093%, respectively in DSR and TPR farm. It may be inferred based on the coefficient of multiple determinations (R^2) that the explanatory viable included in the regression model for paddy are responsible for 88 and 77% variation in DSR and TPR farm, respectively.

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Sesbania brown manuring : a tool for plant establishment and weed management in direct seeded rice

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Rice production systems are undergoing various types of changes and such one change has been the shift from transplanting to direct seeding. In DSR, weeds are the biggest constraint mainly due to the absence of water stagnation. Without appropriate weed management, direct seeded crop may not be successful against transplanted rice. In "brown manuring" practice, rice and *Sesbania* crops are planted together and allowed to grow for 25-30 days, before knocking down *Sesbania* crop with 2,4-D ester @ 0.4-0.5 kg/ha. *Sesbania* surface mulch conserves the soil moisture and supplies 10-15 kg N/ ha on decomposition. Residues, when retained on surface, reduce the emergence of weeds, add organic matter and improve nutrient water interaction. In view of the above, *Sesbania* co-culture was used at GBPUAT, Pantnagar during 2005 and 2006 to evaluate its efficacy against weeds in direct seeded rice. Ten treatment combinations were made with seeding method of *Sesbania*, herbicide application and hand weeding practices, tested in randomized block design with three replications. Significant reduction in weed density was observed with pre-emergence application of pendimethalin @ 1.0 kg/ha alongwith 2, 4-D (0.5 kg/ha) and hand weeding at 30 DAS. It recorded 81% lower weed density compared to no spray of pendimethalin. Average data of two years revealed that weed dry weight was reduced when *Sesbania* was used as brown manure. Broadcasting of *Sesbania* seeds with DSR proved better compared to intercropping both in terms of reducing weed dry weight as well as enhancing grain yield. Hand weeding at 30 DAS increased the grain yield during both the years. DSR+ *Sesbania* (row) + pendimethalin+ 2, 4-D (0.3 kg) 25 DAS+HW recorded the highest yield (6.0 t/ha) mainly due to better control of weeds. Application of 2, 4 D @ 0.5 kg/ha at 25 DAS had some setback on the crop.

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Weed management in direct seeded rice–zero tillage wheat system a step toward sustainable agriculture in Indo-Gangetic plains

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In India, rice-wheat cropping system is the most dominant crop sequence practised in about 12 million ha in the Indo-Gangetic plains and contributes about 73% of the total food grain requirement of the country. Its sustainability is vital to the livelihood of farmers and to the national food security. Traditionally, rice is transplanted at the end of the dry season (May/June) after the land has been flooded and puddled and wheat is sown in ***rabi*** season (Oct./Dec). Constraints related to these traditional practices include the shortage of labour, increasing cost, the relative fertilizer and fuel requirement and late sowing of wheat. Whereas the adoption of direct seeding of rice avoids puddling, retains soil structure and also facilitates early wheat planting. Zero tilling in subsequent wheat crop also saves natural condition of soil. However, weeds are the major problem if not effectively managed in this system. Thus, in view of the above fact, a long term trial had been conducted on direct seeded rice and zero tillage wheat at GBPUAT, Pantnagar to find out the impact of these technologies towards the weed management and sustainability of rice-wheat system. Five rice establishments in main plot and two weed management practices were compared in strip plot design. After harvesting of rice, wheat was sown by Pant Zero till-ferti-seed drill without any tillage. Average of six years data revealed that wet seeded rice recorded the highest grain yield followed by transplanted and direct seeded rice in weed-free situation. In zero tillage rice crops completely failed due to weeds. However, one hand weeding had significant impact on yield losses due to weeds which reduced the yield losses from 98 to 30% in zero tillage rice. Almost similar grain yield was recorded in direct seeded and stale seed bed technique (flush irrigation before final tillage). In wheat, higher grain yield (37.8 q/ha) was recorded in zero tillage as compared to conventional tillage in all the establishment methods of rice except in transplanting. Differences in grain yield (0.97 q/ha) were highest in direct seeded rice in these two establishment methods of wheat due to weeds. Thus, differential effect of crop establishment method of rice and wheat system was observed on grain yield of rice-wheat system.

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Effect of weed management practices and nutrient supply systems on floristic composition of weeds, crop productivity and soil chemical properties in upland rice (direct seeded)–pulse relay cropping system

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Experiments comprising weed management practices and nutrient supply systems were conducted for six years during 2001-02 to 2006-07 at Research Farm of AICRP for Dryland Agriculture, OUAT, Phulbani. The soil was light textured sandy loam. Rice cv. ZHU 11-26 (85 days) was grown during all the years. Pigeonpea cv. UPAS-120 was grown during the 1st year i. e. 2001-02. During other years horsegram cv. Urmi (100 days) was taken as a relay crop. The relay crop was sown 10-15 days before the harvest of rice. Conventional tillage included both summer ploughing (off-season tillage) and preparatory tillage before seeding rice. In case of low tillage, only preparatory tillage was done. Low tillage was supplemented by two interculture operations at 21 and 35 DAS rice in W_2 and one interculture at 25 DAS and pre-emergence spray of butachlor @ 1.0 kg/ha in W_3. Farm yard manure containing 0.5% N was taken as the organic source nutrient. Recommended dose of 60-30-30 kg N-P_2O_5-K_2O/ha was used in rice. Relay pulse was grown with residual fertility. Species-wise weed count was taken using quadrats of size 50 cm x 50 cm. Application of butachlor @ 1.0 kg/ha (W_1) recorded less weed population as compared to non-application of herbicides (W_2 and W_3) due to better control of annual weeds. Conventional tillage included off-season tillage during hot summer. Over seasons, this practice reduced the number of perennial weeds and recorded less number of *Cynodon dactylon* and *Cyperus rotundus* during 2006-07. Integrated supply gave moderate degree of weed control. Conventional tillage+two intercultures recorded the maximum rice equivalent yield of the system and proved significantly superior to other weed management practices during 2003-04. In other seasons, the weed management practices did not differ significantly in respect of rice equivalent yield. Over seasons, convential tillage+two intercultures recorded the mean maximum rice equivalent yield of 14.44 q/ha. Application of 100% inorganic fertilizer recorded less number of weeds but it could not maintain the soil health on a sustainable basis as evident from soil pH and organic carbon content of the soil. Application of 100% N as inorganic recorded the maximum rice equivalent yield of the system during the 1st year of experimentation. In subsequent years, 50% N as organic+50% N performed the best with mean rice equivalent yield of 15.42 q/ha.

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Growth and yield of turmeric as influenced by different weed control treatments

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A field experiment was conducted to study the effect of post emergence application of herbicides at Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana during 2003 and 2004. The treatments consisted of post-emergence application of glyphosate 1.0 kg/ha (before emergence of crop; 30 DAS) and hand weeding at 30-35 days after sowing (DAS) and each was followed by application of metribuzin (0.50 and 0.75 kg/ha), atrazine (0.75 and 1.00 kg/ha), pendimethalin (0.75 kg/ha), hand weeding and control. Study revealed that fresh weed weight decreased significantly in all weed control treatments as compared to control. Hand weeding followed by atrazine (1.00 kg/ha) produced maximum fresh turmeric rhizome yield of 191.7 q/ha and it was statistically similar to HW fb atrazine 0.75 kg/ha, HW fb metribuzin 0.75 kg/ha, HW fb pendimethalin 0.75 kg/ha and three hand weedings. Post-emergence application of glyphosate at 30-35 DAS fb metribuzin, atrazine and pendimethalin was significantly better than control, but was not comparable to HW fb atrazine 1.00 kg/ha.

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Evaluation of resource conservation techniques and herbicides in transplanted rice

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A field experiment was conducted during ***kharif*** season of 2002 in sandy clay loam soil, low in N, medium in P_2O_5 and high in available K_2O and slightly alkaline in reaction at the farmers' fields in two villages i. e. Pirthala and Laloda, district Fatehabad, Haryana. Experiment consisted of four resource conservation techniques/methods of planting viz., unpuddled-transplant, furrow irrigated raised bed system (FIRBS)-transplant, zero-till-transplant and puddled-transplant, and four treatments of herbicides viz., butachlor @1500 g/ha, pretilachlor @1000 g/ha, oxadiargyl @ 70 g/ha and fentrazamide @ 120 g/ha, arranged in 16 treatment combinations. Experiment was laid out in randomized block design (two factorial) with four replications. FIRBS-transplant was realized feasible and comparable to the traditional method of puddling fb transplanting in terms of yield and yield attributes of rice. Fentrazamide at 120 g/ha and oxadiargyl at 70 g/ha each being similar to pretilachlor at 1000 g/ha were found better than butachlor at 1500 g/ha against *Echinochloa crus-galli* when applied at 3 DAT; and consequently resulted in significantly higher number of effective tillers, 1000-grain weight and ultimately higher grain yield of transplanted rice. Panicle length and number of grains (filled and unfilled) among yield attributes, and various growth indices including number of plants/m^2, plant height, number of shoots/m^2 and dry matter accumulation by rice plants and consequently straw and biological yield and harvest index were statistically similar under different methods of planting and herbicidal treatments.

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Control of weeds due to adoption of zero-tillage technology

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The study was conducted in Karnal and Fatehabad districts of Haryana state. Two blocks from Karnal district i.e. Karnal and Nilokheri; two villages from each block, namely, Uchana and Kulvehari (Karnal), Bhaini and Sultanpur (Nilokheri); one block from Fatehabad district i.e. Tohana and three villages, namely, Prithla, Laloda and Nangala were selected with 20 respondents randomly selected from each village for the study purpose having a total sample of 140 users of zero-tillage technology (ZT). The study revealed that most of the respondents were of young to middle age group, mean score of education was not satisfactory. Twelve per cent of the respondents were having more than 15 acres land holding. The average socio-economic status was not satisfactory. Extension contacts, mass media exposure, change proneness and risk orientation were found of low level. Majority of farmers used rice-wheat cropping system. Maximum respondents were of neutral (57.85%) attitude towards ZT. Large majority of farmers (61.42%) were of medium level of overall knowledge of ZT. Maximum respondents of the farmers followed control flooding method of irrigation. It was revealed that by adoption of ZT, a large majority of respondents (82.41%) controlled *Phalaris minor* and other weeds like *Chenopodium album* (7.85), *Rumex* spp. (1.42%) and *Convolvulus* arvensis showed zero control. ZT showed effect in control of *P. minor*, while in others it did not cross 10% level of control.

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Effect of different herbicide treatments on nutrient content and uptake behaviour of weeds and wheat

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A field experiment was conducted during ***rabi*** season of 2002-03 at the Agronomy Research Farm of CCS Haryana Agricultural University, Hisar to evaluate the effect of metsulfuron-methyl as tank mixture or sequential application with grassy herbicides viz., clodinafop, fenoxaprop and sulfosulfuron on nutrient uptake of wheat and weeds. All weed control treatments significantly reduced the total population and dry matter accumulation by weeds than weedy check. Application of clodinafop and fenoxaprop was found very effective in controlling grassy weeds but not effective against broad leaf weeds. Metsulfuron alone and its combination with grassy herbicides effectively controlled all broad leaf weeds. Sulfosulfuron alone controlled both grassy and broad leaf weeds but its efficacy against grassy weeds was lower than clodinafop and fenoxaprop and metsulfuron against broad leaf weeds. Clodinafop *fb* metsulfuron and fenoxaprop *fb* metsulfuron efficiently controlled the complex weed flora and produced grain yield of wheat equal to weed free treatment. Weed population and dry matter accumulation were minimum in these treatments and comparable with weed free check. The nutrient content was not influenced significantly by the herbicide treatments. Therefore, the nutrient removal was governed only by the dry matter production of weeds. Application of herbicides alone or their mixture as well as followed by application reduced the dry matter production of weeds and thereby reduced the removal of N, P and K by weeds. Similarly, nutrient content (N, P and K) in both wheat grain and straw was not influenced by any of the herbicide treatments. Application of clodinafop *fb* metsulfuron, fenoxaprop *fb* metsulfuron, clodinafop+metsulfuron and metsulfuron *fb* clodinafop recorded significantly higher grain and straw yields as well as total N, P and K uptake by crop over rest of the treatments

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Bioefficacy of clodinafop and various herbicide mixtures for weed control in wheat (*Triticum aestivum* L.)

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Two separate field experiments were conducted in wheat during ***rabi*** seasons of 2002-03 and 2003-04 on sandy loam soil, low in available N, medium in available P and higher in available K at Research Farm, Department of Agronomy, CCS Haryana Agricultural University, Hisar. Experiments aimed at evaluating the effect of different formulations and addition of surfactant on efficacy of clodinafop-propargyl and feasibility of various herbicide mixtures against complex weed flora in wheat. Each experiment comprised 17 treatments laid out in a randomised block design with three replications. The major weeds infesting wheat field were *Avena ludoviciana* Dur., *Phalaris minor* Retz., *Chenopodium album* L. and *Convolvulus arvensis* L. Herbicidal treatments, in general, significantly increased the growth parameters, yield attributes and yield of wheat over weedy check. Clodinafop (WP or EC) was effective against grassy weeds only. Higher dose of this herbicide (50 or 60 g/ha) was more effective in controlling weeds as compared to its lower dose (40 g/ha) during both the years. Addition of surfactant (0.3, 0.5 or 1.0%) to clodinafop 15 WP was statistically similar to its application without surfactant at 50 or 60 g/ha. Clodinafop 10 EC+surfactant was at par with its alone application at 40, 50 or 60 g/ha. Tank mix application of clodinafop 10 EC+metsulfuron-methyl 20 WP (10 : 1) at 50 or 60 g/ha provided efficient control of complex weed flora resulting in higher values of growth parameters, yield attributes and yield of wheat and this treatment was next best to weed free conditions. Fenoxaprop and clodinafop were effective only against grassy weeds, whereas sulfosulfuron controlled both grassy and broad leaved weeds. Metribuzin applied alone or as tank mixture with clodinafop (WP or EC) resulted in effective control of weeds, however, it also caused significant reduction in number of spikes, crop dry matter, yield attributes and yield of wheat.

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Assessment of critical period of crop-weed competition in late planted sugarcane

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The reduction in cane yield due to weed infestation ranges from 10 to 70% depending upon nature, intensity and period of occurrence of weeds. Timely control of weeds during critical crop-weed competition period is important for minimizing losses. Thus, establishing the critical period of competition is essential to develop effective and economical weed control measures for a long duration crop. The experiment was conducted during 2001-02 and 2002-03 at Karnal to find out the effect of weeds at various periods of crop growth on weed biomass and productivity of late planted sugarcane (after wheat harvest). The field soil was loamy sand having pH 7.8, low in available N, medium in P and K content. Variety CoH 110 was planted in first week of May during both the years with 10 treatments comprising weedy and weed free condition each upto 30, 45, 60 and 75 days after planting (DAP) and throughout crop life period. The experiment was laid out in RBD with three replications. Except in weed management treatments, all other agronomical practices were followed as per recommendation for the crop in the region. *Cyperus rotundus* was the most dominant weed with 48% relative intensity followed by *Echinocloa colona* (17%), *Cynodon dactylon* (13%), *Melilotus indica* (10%) and *Trianthema portulacastrum* (7%). Maximum dry matter of weeds was recorded under weedy conditions throughout the crop growth period. Lowest weed dry matter was recorded under the treatment of weed free upto 60 DAP. The effect of treatments on sugarcane production revealed that maximum number of tillers, millable canes and cane yield were recorded from the treatment of weed free throughout the crop growth period, which were statistically similar to weed free upto 60 DAP and weedy upto 30 DAP. Other treatments were significantly inferior, thus critical period of weed management in late planted sugarcane was found between 30 to 60 DAP.

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Phytotoxicity of pendimethalin in wet direct seeded rice

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Field experiments were conducted during ***kharif,*** 2007 at CCS HAU Regional research Station, Karnal on efficacy of pendimethalin in wet direct seeded rice. Sowing of pre-germinated seed of two cultivars HKR 47 (dwarf) and CSR 30 (basmati) was done in puddled and unpuddled conditions in standing water. Data revealed that there was phytotoxicity on rice seedlings by sand mix application of pendimethalin at 1.0 and 1.5 kg/ha at eight days after sowing (DAS). The phytotoxicity was more at higher dose. The damage to rice seedlings was more in basmati variety CSR 30 than the dwarf rice variety HKR 47. Slightly higher phytotoxicity was observed in un-puddled than the puddled conditions, which might have been due to slight covering of seed in soil under puddled situations. In CSR 30, there was 55 and 70% damage due to pendimethalin 1.5 kg/ha under puddled and unpuddled conditions, respectively. However, there was 50% phytotoxicity at 1.0 kg/ha dose under both the situations. In HKR 47, there was 20 and 35% damage due to pendimethalin 1.5 kg/ha under puddled and unpuddled conditions, respectively; however, the respective damage at 1.0 kg/ha was 5 and 10%. Similar effects were also reflected in terms of reduced density and height of rice plants, and fresh and dry weight in the plots treated with pendimethalin. In another experiment at RRS, Karnal, spray of pendimethalin at 1.0 and 1.5 kg/ha after 7 DAS caused 95% phytotoxicity to wet seeded basmati rice CSR30 under unpuddled conditions where pre-germinated seeds were sown with drum-seeder. Other farmers' field trials in district Kaithal revealed that sand mix application of pendimethalin at 1.5 kg/ha at 10 DAS resulted in 60 and 85% mortality to different dwarf and basmati rice cultivars, respectively, sown with drum-seeder or broadcast under puddled as well as un-puddled conditions. Pendimethalin at 1.5 kg/ha even at 13 DAS caused 40% damage to pre-germinated broadcast sown basmati rice cultivars HBC 19 and CSR 30 under puddled conditions in village Teek, Kaithal. Based on present investigation, we conclude that pendimethalin should not be used for selective weed control in wet seeded rice using pre-germinated seeds under puddled as well as unpuddled conditions.

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Comparative studies on the influence of weed population and dry weight under different methods of planting and irrigation schedules

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The zero tillage technology by advanced sowing and bed planting by mechanical control of weeds in wheat may reduce the dependence on herbicides for the control of weeds. The present studies were conducted at PAU, Ludhiana in ***rabi*** 2005-06. The treatments consisted of three planting methods such as ZT (zero till), CT (conventional till) and BP (bed planting) in main plots, three first irrigation levels at 2, 3 and 4 WAS in sub-plots and three subsequent irrigation levels at IW/CPE ratio of 1.2, 1.0 and 0.8 in sub-subplots and evaluated in strip plot design with three replications. The soil of experimental field was loamy sand in texture with pH 8.3, low in available N (185 kg/ha), medium in available P (13.25 kg/ha) and high in available K (247.5 kg/ha). The wheat cultivar PBW 343 was sown with tractor drawn zero till drill using 100 kg seed/ha and bed planter using 75 kg seed/ha on 67.5 cm wide beds with two rows on each bed. At sowing, half dose of nitrogen (62.5 kg/ha) and full dose of phosphorus (62.5 kg/ha) was broadcasted through urea and DAP, respectively. The remaining half dose of nitrogen (62.5 kg/ha) was broadcasted with first irrigation. For control of weeds, one post-emergence spray of sulfosulfuron 75 WG @ 32.5 g/ha was done at 40 DAS. Grain yield of wheat under ZT (38.4 q/ha), conventional tillage (38.7 q/ha) and bed planted wheat (41.9 q/ha) was similar to each other. There were no significant differences in the grain yield in first irrigation levels. However, irrigation applied at 1.2 and 1.0 IW : CPE ratio produced (41.53 and 39.86 q/ha) significantly higher grain yield than that of irrigation applied at 0.8 IW : CPE (37.49 q/ha) but were similar to each other. The predominant weed flora was *Rumex spinosis*, *Chenopodium album* and *Lepidium sativa*. The number of broad and narrow leaved weeds was less under ZT and BP as compared to CT. The number of weeds decreased drastically after herbicide spraying and no difference in weed count was found in treatments upto harvest. Dry matter of weeds before spray of herbicide was considerably less in ZT plots as compared to BP and CT but it was also less in BP than CT. After spraying of herbicide, no differences were recorded in dry matter of weeds among the treatments. At harvest also higher dry matter of weeds was recorded under CT. The irrigation treatment did not influence the dry matter of weeds before and after spraying of herbicide and at harvest.

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Efficacy of post-emergence herbicides against mixed weed flora in soybean (*Glycine max*) under mid-hill conditions of Himachal Pradesh

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Field experiments were conducted at the experimental farm of Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during 2004 and 2005. The experiment was laid out in randomized block design with three replications and 10 treatment combinations. The treatments included three doses of quizalofop-ethyl (40, 50 and 60 g/ha), and two doses of chlorimuron-ethyl (9 and 12 g/ha) and combination of quizalofop 50 g/ha with chlorimuron-ethyl 9 and 12 g/ha alongwith pendimethalin 1.5 kg/ha and weed free treatment. The soil of the experimental site was silty clay loam in texture, acidic in reaction (5.8), low in nitrogen and phosphorus and medium in potassium status. Results revealed that quizalofop 50 g/ha being similar to 60 g/ha completely controlled the grassy weeds and also resulted in significantly higher soybean seed yield as compared to lower doses of quizalofop. On the other hand, chlorimuron 9 g/ha being similar to its higher doses controlled the broad leaf weeds most effectively and grassy weeds poorly. However, mixed application of quizalofop 50 g/ha+chlorimuron 9 g/ha controlled both grassy and broad leaf weeds and resulted in higher soybean seed yield which was similar to that of weed free treatment but significantly higher over all other treatments.

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Influence of row spacing and weed control methods on weeds, yield and economics in *Gobhi-sarson (Brassica napus* L.)

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To study the effect of row spacing and method of weed management on weeds, productivity and economics of *Gobhi-sarson*, a field experiment was conducted at the experimental farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during ***rabi*** 2002-03 and 2003-04. Fourteen treatment combinations of seven weed management [three rates of clodinofop (45, 60 and 75 g/ha] and sequential application of pendimethalin 0.75 kg/ha (pre.) fb clodinafop 45 g/ha (45 DAS) plus three checks (pendimethalin 1.5 kg/ha (pre.), hand weeding twice and unweeded] treatments and two row spacings (20 and 30 cm) were evaluated in factorial randomized block design with three replications. The soil of the experimental field was silty clay loam and acidic (pH 5.8) in reaction. The *Gobhi-sarson* variety HPN-3 was sown during the second week of November and harvested by last week of April each year. The experimental field was mainly infested with grassy weeds viz., *Phalaris minor, Avena fatua* and *Lolium temulentum* constituting 81.5% of the total weed flora. The broad leaf weeds constituted only 18.5% of total weed flora. The results reveal that hand weeding twice was most effective in decreasing the population and dry matter of weeds with weed control efficiency of 80.1% and in increasing the yield attributes and yield of *Gobhi-sarson.* However, it was statistically similar with pendimethalin 0.75 kg/ha (pre.) fb clodinafop (45 DAS), clodinafop 75 g/ha and pre-emergence application of pendimethalin 1.5 kg/ha. Post-emergence application of clodinafop 75 g/ha was most effective in controlling the grass weeds with weed control efficiency of 97.5%. Unchecked weed growth reduced the seed yield to the tune of 61.6% over the best treatment i. e. hand weeding twice. The closer sowing of *Gobhi-sarson* at 20 cm spacing significantly decreased the weed count and dry matter accumulation of all the weeds. Closer row spacing increased seed yield of Gobhi-sarson 5.1% than wider spacing of 30 cm. Pendimethalin 0.75 kg/ha (pre.) fb clodinafop (45 DAS) in combination with 20 cm spacing resulted in highest net returns and benefit : cost ratio.

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Efficacy of tank mix and sequential application of pinoxaden with metsulfuron-methyl for broad spectrum weed control in wheat (*Triticum aestivum* L.)

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Clodinafop-propargyl, fenoxaprop-P-ethyl and sulfosulfuron provide excellent control of grassy weeds in wheat. Continuous use of same herbicide for many years may result in development of resistance against some weeds. Moreover, complaints of poor efficacy of fenoxaprop and sulfoslufuron against isoproturon resistant populations of *Phalaris minor* are also being received from farmer's fields and have been documented recently. A new herbicide pinoxaden 5 EC developed against grassy weeds in wheat has the potential for use against resistant populations of *P. minor*. 2,4-D provides effective control of common lambsquarters and other broad leaf weeds but only partial suppression of hardy broad leaf weeds viz., *Rumex dentatus*, *Vicia sativa* and *Anagallis arvensis*. Metsulfuron is very effective against these broad leaf weeds and has no compatibility issues with grass herbicides. To study the efficacy of tank mix and sequential application of pinoxaden with metsulfuron for broad spectrum weed control in wheat, a field experiment was conducted during the winter season of 2006-07 on a sandy loam soil at Agronomy Research Area of CCS Haryana Agricultural University, Hisar. Fifteen herbicide treatments comprising pinoxaden at 40, 45 and 50 g/ha alone and in combination with metsulfuron at 4 g/ha as tank mix and sequential application were compared with untreated and weed-free checks. The density of weeds decreased significantly due to different herbicide treatments compared to untreated check at 60 DAS. Pinoxaden alone at 45 and 50 g/ha provided excellent control of grassy weeds but did not show any efficacy against broad leaf weeds and provided 80-90% control of grassy weeds. Metsulfuron at 4 g/ha brought about significant reduction in weed density as compared to weedy check and 100% control of broad leaf weeds. Tank mixture of pinoxaden+metsulfuron and sequential application provided 80-95% control of grassy and 85-100% control of broad leaf weeds. All the herbicide treatments registered significantly higher crop yield over weedy check.

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Evaluation of clodinafop propargyl+metsulfuron methyl (CIL/ H- 406) against complex weed flora in wheat

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Phalaris minor and *Avena ludoviciana* often appear in wheat with many broad leaf weeds in different cropping systems in India. *P. minor* has been at number one in rice wheat cropping system. Due to effective control of *P. minor* with alternate herbicides, *Rumex dentatus*, *Malwa parviflora* and *Convolvulus arvensis* along with many other broad leaf weeds frequently started infesting wheat fields in rice-wheat cropping system. The problem of complex weed flora in wheat was successfully solved through sequential application of clodinafop, fenoxaprop or sulfosulfuron at 30-35 DAS fb 2, 4-D or metsulfuron after a week. But it requires two separate operations for such application and thus, adds to cost. Another herbicide sulfosulfuron+metsulfuron-readymix formulation (Total) was recommended against complex weed flora and it did very well but residual toxicity of this herbicide on succeeding crops (sorghum and maize) in rotation put a question mark on its wide acceptability. In order to have another suitable alternative against complex weed flora in wheat under different cropping sequences, the performance of CIL/H-406 (clodinafop propargyl 15%+metsulfuron-methyl 1 %, WP) was studied during ***rabi*** season of 2006-07 at Research Farm of Department of Agronomy, CCS Haryana Agricultural University, Hisar as well as at farmers' fields. Among different herbicidal treatments, clodinafop 60 g/ ha was found very effective (98%) only against grassy weeds and it reduced the density and dry weight of these weeds significantly. Metsulfuron 4 g/ha was very effective (90%) against broad leaf weeds but it did not control grassy weeds. Sequential application of clodinafop 60 g fb metsulfuron 4 g/ ha proved very effective against complex weed flora and it controlled grassy and broad leaf weeds to the extent of 99 and 95%, respectively. The density and dry weight of grassy as well as broad leaf weeds were reduced with corresponding increase in the dose of CIL/H-406. However, CIL/H-406 at 60+ 4 g/ha and its higher doses were equally effective against mixed weed flora compared to sequential application of clodinafop 60 g fb metsulfuron 4 g/ha. Among different herbicidal treatments, CIL/H-406 at 60+4 g and clodinafop fb metsulfuron 60 and 4 g/ha recorded the number of spikes, 1000-grain weight and grain yield of wheat statistically similar to that of weed free check and it did not cause any crop phytotoxicity. There was no residual toxicity on succeeding crops of rice, sorghum and mungbean.

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Optimisation of castor production under resource constraints

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Castor is cultivated around the world because of the commercial importance of its oil. India holds a premier and dominant position in castor production and supplies. India accounts for nearly 60% of world castor area and 65% of world production (2004-05) and ranks first both in area and production. Cultivation of castor in Haryana is quite successful and productivity is second next only to Gujarat. Proper exploitation of castor would not only earn valuable foreign exchange for the country, but would also help in improving the socio-economic backwardness of the castor growing regions as well as castor growers in the country. Castor production is beset to several problems in different regions. Studies were conducted at Regional Research Station, Bawal during ***kharif*** 2006-07 to evaluate production factors like nutrient (fertilizer), weed management, moisture, plant protection and their effect individually and in combination for quantification of response to castor production. This has helped to prioritize the critical production factors limiting the castor production under rainfed condition. Constraints free situation with the adoption of the full package resulted in the maximum seed yield (1875 kg/ha). No application of fertilizers and weeding treatments being statistically similar was found most detrimental in castor production. No fertilizer and weeding treatments produced seed yield of 994 and 1035 kg/ha, respectively. Non-adoption of the critical inputs resulted in significant reduction in plant height, number of spikes per plant and 100-seed weight and the production was reduced >50% compared to full package. Thus, weeding and fertilizer emerged as the most critical factors for enhancing castor production.

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Chemical weed control in onion nursery

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A field study was conducted at Punjab Agricultural University Regional Station, Bathinda during 2005-06 and 2006-07 to evaluate the effect of different weed control treatments on germination, growth of onion seedlings and weed spectrum in onion nursery on sandy loam soil having pH of 8.5, low in organic carbon, medium in phosphorus and high in potash. The experiment was conducted in randomized block design with 10 treatments viz., unweeded control, weed free, plastic mulching (pre- plant), pendimethalin (pre-emergence), oxyflourfen (post-emergence) with four replications. All the treatments reduced weed growth significantly over the unweeded control except plastic mulching and oxyflourfen at 0.025 kg/ha. Pendimethalin at all the three levels significantly reduced weed population but adversely affected the germination of onion seedlings. The most adverse effect of pendimethalin was observed when it was applied at 1.0 kg/ha. However, oxyflourfen arrested the weed as well as seedling growth but it did not control weeds completely and moreover it significantly reduced the population of dicot weeds during both the years. There was significant reduction in weight of 100 seedlings at all the oxyflourfen levels. Although pendimethalin at 0.5 kg/ha affected seed germination, but it gave comparatively good control of weeds during both the years. Plastic mulching also significantly reduced growth and population of weeds. Number of healthy seedlings was also reduced with increasing levels of herbicides during both the years of study.

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Current weed management practices in wheat in rice-wheat cropping system of Haryana

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A survey was conducted during 2007 to study the weed management practices in wheat in the rice-wheat cropping system of Haryana. The most common current weed management practices in wheat included use of post-emergence herbicides. Many farmers are familiar that zero tillage suppresses the infestation of *Phalaris minor* in wheat. Primary tillage has decreased due to adoption of zero tillage in last 5-10 years. Negligible number of farmers used hand weeding. The top 10 most common weeds of wheat include *Phalaris minor*, *Rumex dentatus*, *Melilotus indica*, *Chenopodium album*, *Malwa parviflora*, *Medicago denticulata*, *Polypogon monspeliensis*, *Lathyrus aphaca*, *Coronopus didymus* and *Avena ludoviciana*. The study showed that during last five years infestation of *R. dentatus*, *M. parviflora* and *P. monspeliensis* increased while that of *Cirsium arvense*, *C. album*, *Convolvulus arvensis*, *Asphodelus tenuifolius* and *Vicia sativa* had decreased. The use of isoproturon has been phased out. It has been replaced by clodinafop, sulfosulfuron and fenoxaprop. At present, majority of farmers are using clodinafop and sulfosulfuron. In addition to 2,4-D, use of new herbicides like metsulfuron-methyl and to some extent carfentrazone (primarily against *M. parviflora*) is increasing. Red signals of resistance in few biotypes of *P. minor* against sulfosulfuron and clodinafop and in many biotypes of *P. minor* against fenoxaprop have been reported. Use of fenoxaprop has decreased considerably. Such mild failures are important to understand that the future pain is inevitable if corrective measures are not taken immediately. Even if the verification of resistance of *P. minor* against alternate herbicides is eventually completed in next 2-3 years, some of the herbicides like clodinafop which have the potential for continued success need to be guarded more vigorously. It is important to restrict the use of any individual herbicide in alternate years instead of every year. Another option is to persuade farmers to use booms fitted with multiple-flat fan nozzles. Training programme on spray techniques must be strengthened. Majority of the farmers still perceive herbicide resistance as major problem and there is strong need for new molecules with different modes of action.

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Herbicide-resistant crops and glyphosate-resistant weeds : current status and future outlook

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Commercialization of biotechnology-derived bromoxynil-resistant cotton and glufosinate-resistant canola in 1995 and glyphosate-resistant soybean in 1996 heralded the beginning of a new era in weed management. To date, only five transgenes have been used in crops to confer resistance to bromoxynil, glufosinate, and glyphosate. Of the three herbicides, only glyphosate had a significant impact on weed management. Glyphosate-resistant crops as weed management tools have provided farmers the simplicity and flexibility to manage a broad-spectrum of weeds effectively and profitably. Because of these agronomic and economic benefits, glyphosate-resistant crops (soybean, cotton, canola and corn) have dominated the herbicide-resistant crop market. The high level of adoption of glyphosate-resistant crops by farmers has significantly reduced the value of remaining herbicide market and reduced competition for discovery of new herbicides. Increased adoption of glyphosate-resistant crops has dramatically increased the use of glyphosate, with a concomitant decrease in the use of other herbicides. Wide spread adoption of glyphosate-resistant crops has not only shifted weed species in these crops towards more tolerant species (weed shifts), but also resulted in the evolution of weeds resistant to glyphosate. To date, 13 weed species have evolved resistance to glyphosate, globally. Among the 13 species, *Amaranthus palmeri*, *Amaranthus rudis*, *Ambrosia artemisiifolia*, *Ambrosia trifida*, *Conyza canadensis*, *Lolium multiflorum* in the USA, *Sorghum halepense* in Argentina and *Euphorbia heterophylla* in Brazil have evolved resistance in glyphosate-resistant crops. The problem of glyphosate-resistant weeds is real and continuous use of glyphosate without alternative strategies will likely result in evolution of more glyphosate-resistant weed species in the near future. Evolved glyphosate resistant weeds are a major risk for the continued success of glyphosate-resistant crops. Glyphosate is a global herbicide of the century and it is imperative to maintain diversity in weed management systems for glyphosate to be sustainable. Despite great success with other glyphosate-resistant crops, glyphosate-resistant sugarbeet was not grown (fear of consumer rejection) and wheat was not commercialized. Bromoxynil-resistant cotton and canola were recently withdrawn from the market for economic reasons. The future of herbicide-resistant crops depends on many factors : potential new herbicide-resistant crops; introduction of a crop resistant to multiple herbicides (stacked genes); fear of consumer rejection of products; global public acceptance; grower economics; and weed shifts and resistance.

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Struggling with herbicide resistance : one step beyond

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Since a *Daucus carota* biotype resistant to 2,4-D was first described in Canada in 1952, 315 biotypes resistant to herbicides have been reported worldwide. For example United States, a country with one of the most advanced agriculture has had an exponential growth in the cases of herbicide resistant weed biotypes reported. With 172 resistant biotypes described in the 90s, some of them show cross and multiple resistance to several herbicides now, making more difficult their control. At the beginning of the 21st century, the genetic modified crops (GMC) have been widely used in USA. But, the continuous use of glyphosate alone, without mixtures with herbicides from alternative mode of action, has been one of the main reason of the evolution of herbicide resistance in both dicots and monocots (37% of the reported cases of herbicide resistant are against the glycine group). Now-a-days, two key questions remain : "Is our knowledge about molecular biology, biochemistry, physiology and agronomy good enough to solve the herbicide resistance problem by using integrated weed management?" If yes : "Why the farmers do not believe in that and they continue using traditional management methods?"

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Herbicide resistant weeds in South America

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In South America, herbicide resistant weeds were first detected against propanil herbicide in Colombia, early in the 1990's, on *Echinochloa* species found in rice crop. In the mid 1990's, herbicide resistant weed biotypes were documented in Brazil. Now-a-days, in Brazil there are 17 herbicide resistant weed species, which are resistant to five herbicide groups, and two species with multiple resistance. The resistance includes different target sites such as : ACCase (*Brachiaria plantaginea, Digitaria ciliaris* and *Eleusine indica)*, ALS (*Bidens pilosa, B. subalternans, Cyperus difformis, Fimbristylis miliacea, Parthenium hysterophorus* and *Raphanus sativus)*, EPSPS (*Conyza bonariensis, C. canadensis, Euphorbia heterophylla,* and *Lolium multiflorum)*, cell wall synthesis-quinclorac (*Echinochloa crus-galli,* and *Echinochloa crus-pavonis*), and PPO (*Euphorbia heterophylla)*. Multiple resistance has been confirmed in *E. heterophylla* for ALS and PPO, and for ALS and glyphosate. Weed resistance to herbicide has been spread to almost 20 states in Brazil, infesting more than 2 million hectares resulting in losses over 100 millions of dollars. Herbicide resistant weeds have been documented in several other countries of South America : Argentina, Bolivia, Chile, and Paraguay. In Argentina, the first herbicide resistant weed was documented on the middle 1990's in *Amaranthus quitensis* for ALS inhibitors. Now-a-days, glyphosate resistant *Sorghum halepense* was documented in Argentina. In Paraguay and in Bolivia, ALS resistance was detected in *E. heterophylla* at the end of the decade of 1990. In Chile, glyphosate resistant weed was found in *L. multiflorum* in 2001. Limited resources (personnel, time and funding) invested on herbicide resistance investigation and training is a common feature in Latin America. However, anecdotal evidence from worldwide experience suggests research and education are not enough to avoid the evolvement of herbicide resistant weeds and other actions might be necessary to solve the problem.

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Molecular analysis of *Phalaris minor* populations in India – Its implications in weed management

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Random amplified polymorphic DNA analysis has been conducted on isoproturon susceptible and resistant *P. minor* populations from different wheat growing states in India. This was done with a view to assess the genetic diversity amongst these populations. A single alternate herbicide is expected to provide desirable control in homogenous populations, while this may not be so in case of heterogenous populations. This would also help ascertain the pattern of origin of herbicide resistant populations and mode of their spread. Ten isoproturon susceptible populations from different locations in India viz., Jabalpur, Gwalior, Pantnagar, Palampur, Faizabad, Samastipur, Ranchi, Uchani-Karnal and HAU Farm Hisar were selected for the study. Also 10 isoproturon resistant populations from different locations in Punjab and Haryana viz., Ludhiana, Amritsar, Sangrur, Kapurthala,Uchana-Karnal, Sagga-Karnal, Dabra-Hisar, Bhiwani, Ambala and Kaithal were included and 11 random primers selected from previous studies on *P. minor* were used for amplification of DNA. Dissimilarity values amongst susceptible biotypes ranged from 0.091 to 0.86 and amongst resistant biotypes ranged from 0.049 to 0.95 indicating high level of heterogeneity within these populations. Cluster tree analysis grouped the susceptible biotypes into two major groups and the resistant biotypes into three groups. Resistant biotypes of groups 1 and 2 intermingled with the susceptible biotypes of groups 1 and 2, respectively, indicating the evolution of resistance to isoproturon in the two groups independent of each other. Some of the resistant populations diverged extensively to form a separate third group. The data suggest that due to high level of heterogeneity observed, recommendations of any one herbicide for all the populations could give variable results. Some of the susceptible/ resistant populations match more closely to distantly located populations indicating their common origin and transport into newer areas with seed.

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Overexpression of EPSPS for herbicide (glyphosate) resistance in tomato through *Agrobacterium* mediated gene transfer

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Glyphosate is widely used as a broad-spectrum weed control agent. It interferes with normal plant metabolism through inhibiting the enzyme EPSPS (5-Enol Pyruvyl Shikimate-3- Phosphate Synthase). In plants and microorganisms, EPSPS is involved in the biosynthesis of aromatic aminoacids, vitamins and many secondary metabolites. As a consequence of the inhibition of aromatic aminoacid biosynthesis, protein synthesis is disrupted, resulting in the plants' death. Keeping this in view, the transgenic approach to develop herbicide tolerance in tomato study was focused on expressing a modified EPSP with altered kinetics to minimize binding of glyphosate to EPSPS. The EPSPS gene was codon optimized for solanaceous species and synthesized. The gene was modified in such a way that it had altered binding characteristics to glyphosate. The kinetic constants of the modified gene were worked out such that the enzyme had a low Km for PEP and high Ki for glyphosate. *Agrobacterium* mediated *in planta* transformation was adopted to develop transgenics expressing EPSPS. Two days old tomato seedlings were pricked at the apical meristem and infected in *Agrobacterium* suspension. Later, they were shifted to autoclaved soil for a few days before sifting them into pots under greenhouse conditions. The T_0 plants grew, flowered and set seed normally and resulted in 14 T_0 plants for PEGAD-EPSPS. T_1 seeds were collected and analysis of T_1 transformants was carried out. The T_1 plants were screened at seedling level and whole plant level with the concept that if the T_1 seeds germinate in glyphosate medium and can survive (growth recovery), they can be considered putative transformants. The recovered seedlings from the primary level were again screened at plant level by developing leaf swabbing bioassay. A single leaf was swabbed with 2000 ppm glyphosate and the plants which did not show any chlorotic symptoms even after five days of swabbing were selected as putative transformants and analyzed further by PCR. The primer specific to 35S promoter specific designed for EPSPS gene was used and 750 bp amplified product in plants transformed with pEGAD-EPSPS was obtained. The level of shikimic acid was estimated and found that the accumulation of shikimate in relatively higher levels in treated controls (2000 ppm of glyphosate) when compared to transgenics. In the transgenics, the chlorophyll degradation was less when treated with glyphosate. These transformants also maintained higher membrane integrity and RWC. The recovery growth was substantially high in transgenics after treating with glyphosate.

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Bioefficacy studies for herbicide tolerant transgenic maize under field conditions

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Transgenic crops are increasingly becoming important in several countries including India. Globally, maximum area under transgenic crops is occupied by herbicide tolerant crops. Majority of maize is grown as rainfed crop across India. Herbicide tolerant maize which confers resistance to Roundup a post-emergent non-selective herbicide is being used in many parts of the world. The discovery of herbicide tolerant crops for weed control is proving more economical as they simplify weed management and provide broad spectrum control. The field trial of transgenic maize [Roundup Ready™ Corn Hybrids (Event–NK 603)] conferring tolerance to glyphosate was conducted with objectives to study bioefficacy of herbicide tolerant maize expressing CP_4 EPSPS gene and to work out cost : benefit ratio vis-a-vis prevailing weeding practices. The thrice replicated experiment was treated with eight different dosages of glyphosate as single or double sprays after 20 and 40 days of germination. The spray was given over the top. Weed control efficiency of herbicide treatment was more than 98%. There were no symptoms of crop phytotoxicity and stand loss in maize. Results further show that all herbicide treatment caused significant reduction in weed dry weight when compared with weedy check. The standard cost of cultivation was worked out for maize crop. Considering the treatment cost of herbicide, the cost : benefit (C : B) ratio was highest 1:1.86 in the treatment when single application (2.5 l/ha) of glyphosate was sprayed with grain yield 131 q/ha which was maximum and it was 113.5 q/ha in farmers' practice having C : B ratio 1:1.40.

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Herbicide resistance in *Phalaris minor* and management options

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Herbicide resistance in *P. minor* against isoproturon in rice-wheat cropping system in India was reported in 1992-93. The resistance affected area ranges between 0.8 and 1.0 million hectares in N-W India mostly contained in the states of Punjab (0.3 m ha) and Haryana (0.5-0.6 m ha). Resistance factor in some of the *Phalaris* biotypes was found as high as 15 times. Red signals of resistance reported against other alternate herbicides (fenoxaprop, sulfosulfuron and clodinafop) in few biotypes of *P. minor* are again more serious causes of concern. Fenoxaprop is almost phased out and the level of satisfaction regarding performance of sulfosulfuron and clodinafop is also decreasing year after year. The resistance factor in respect of these alternate herbicides has also increased considerably (2-5 times). Diagnostic survey conducted in 2005-06 indicated that large number of farmers used lower than the recommended dose of herbicides, lower spray volumes, improper time of spray and most farmers applied these herbicides using knapsack sprayer fitted with a single flood jet/cut or hollow cone nozzle instead of flat fan nozzle. Wheat seed contamination with *P. minor* is consistently enriching the soil seed bank. Survey conducted during 2006-07 also reflected more or less similar pictures and also indicated some shift in weed flora. Herbicide resistance in *P. minor* is still being perceived as most serious issue by the growers in rice-wheat cropping system. Looking into the current scenario, it appears that the problem of herbicide resistance in *P. minor* is again at the door steps. Therefore, immediate efforts are required to tackle this problem by integrating all possible resistance management options including mechanical and cultural practices (stale seed bed, improved and certified seed of competitive variety, close spacing and higher seed rate, early sowing, avoid sowing on moist soil, crop rotation, bar harrow/tooth harrow, inter-culture, avoid straw burning, roughing etc.), cultivation/tillage (zero tillage, furrow irrigated raised bed system and laser levelling), new herbicides and their proper use (alternate herbicides/new molecules, herbicide mixtures or sequences, herbicide rotation, proper spray techniques, synergists and safeners, economic thresholds, etc.), monitoring shift in weed flora, regular survey on herbicide resistance, quantification and characterization of resistance, introduction of herbicide resistant crops (HRCs), farmers' participatory approach and trainings, and collaboration with national and international institutes with multidisciplinary approach.

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Zero tillage–a novel way to beat herbicide resistance in wheat in rice-wheat cropping system of Indo-Gangetic plains

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The resistance in the *Phalaris minor* in Rice-Wheat Cropping System (RWCS) was the product of monoculture of rice and wheat, the use of isoproturon as a single herbicide, lack of compliance by farmers, lack of knowledge of scientists and lack of alternate herbicides due to economic limitations. Isoproturon against which the resistance occurred was completely withdrawn in 1995 and was replaced by more effective herbicides like clodinafop, sulfosulfuron and fenoxaprop in 1997-98. Although still there are no large scale *P. minor* control failures, but the way sporadic weed control failures that have been observed in Haryana, herbicide resistant *P. minor* problem will re-emerge as a major issue in few years. Studies at CCS Haryana Agricultural University, Hisar have already shown that herbicide resistance against isoproturon is an irreversible process. There is, therefore, a significant ramification for our herbicide resistance management policy especially when the indications of re-emergence herbicide resistance are already available in Haryana. As happened in case of isoproturon, the continuous use of clodinafop, sulfosulfuron and fenoxaprop for almost nine years now is leaving more space and nutrients for resistant ones to thrive. Genes for resistance thus will spread through the population unless such herbicides are used carefully and in rotation. However, the interaction of *P. minor* with various ecological factors like early sowing, zero tillage, crop rotation and the use of clean seed show that they interact in a significant way and such interaction can help avoiding or at least delaying the resistance. Zero tillage and early sowing did not allow *P. minor* to have a selective advantage as has been happening when sowings were done late and with conventional tillage. Exactly how *P. minor* interact favourably depends on the unfavourable temperature for *P. minor* emergence due to early sowings and less emergence of this weed from deeper layers in zero tilled fields. Experiments when performed on large size plots in the whole Indo-Gangetic plains including Harayna, Punjab, Western Uttar Pradesh and Eastern Uttar Pradesh have shown the virtues of zero tillage in the form of decreased *P. minor* population. This will lead to avoiding or delaying herbicide resistance, possibility of skipping herbicide use in one out of 2-3 years and environmental protection. The outcome of this research opens a novel way of looking at the problem of resistance and its management strategy.

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Evaluation of UPH-206 and metsulfuron methyl for weed control in wheat

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A field trial was conducted during ***rabi*** seasons of 2005-06 and 2006-07 at G. B. P. U. A. & T., Pantnagar to evaluate the bio-efficacy of UPH-206 at 300,400 and 500 g/ha against complex weed flora of wheat and metsulfuron methyl (MSM) 20 WP at 15, 20 and 25 g/ha against broad leaf weeds of wheat. MSM (Algrip), sulfosulfuron 75 WG at 33.75 g/ha and clodinafop-propargyl 15 WP at 400 g/ha along with two manual weeding at 35 & 55 days after sowing (DAS) and weedy check were kept for comparison. All the treatments were replicated thrice in randomized block design. *Phalaris minor* and *Avena fatua* among grasses, *Chenopodium album, Melilotus* sp, *Medicago denticulata, Fumaria parviflora, Vicia sativa, Rumex* spp., *Anagallis arvensis, Coronopus didymus, Lathyrus aphaca* and *Polygonum* spp among broad leaf weeds were found in weedy check plots. Grassy weeds contributed about 62.5%, while contribution of broad leaf weeds to the total weed population was 37.5% in the weedy check plots. The lowest weed density of grassy weeds at 60 DAS was recorded with the application of UPH-206 @ 500 g/ha being similar to UPH 400 g/ha, two manual weeding and clodinafop-propargyl. UPH-206 at 500 g/ha was also found superior over rest of the treatments for the control of broad leaved weeds; however, it was similar to UPH-206 at 400 g/ha, MSM (UPL) at 20 and 25 g/ha and MSM (Algrip) at 20 g/ha. Uncontrolled weeds on an average reduced the grain yield of wheat about 53% when compared to manual weeding twice at 35 and 55 DAS. The maximum grain yield (4170 kg/ha) was recorded with the application of UPH-206 at 500 g/ha followed by UPH-206 at 400 g/ha and manual weeding at 35 and 55 DAS, though statistically similar to each other.

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Studies on efficacy of new herbicides for weed control in soybean under different sowing methods

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An experiment on weed control using new herbicides under different sowing methods in soybean was conducted in Pulses Section of Department of Plant Breeding, Genetics & Biotechnology, Punjab Agricultural University, Ludhiana, during ***kharif*** 2006. Sowing methods i. e. raised bed planting (2 rows/bed of 67.5 cm) and flat planting (45 cm spacing) could not differ between each other in seed yield and weed biomass. Maximum seed yield and minimum weed biomass at harvest were recorded in quizalofop-p-ethyl 5 EC 50 g/ha+chlorimuron-ethyl @ 9 g/ha applied post-emergence (POE) which was statistically similar to imazethapyr 10% SL @ 75 g/ha (POE) and pendimethalin 30 EC @ 0.45 kg/ha (pre-emergence) which was statistically better than quizalofop-p-ethyl 50 g/ha (POE), hand weeding and weedy check. But, quizalofop 50 g/ha and two hand weedings produced significantly more yield and less weed biomass than weedy check. Similarly, higher trend of yield attributes was observed in quizalofop 50 g/ha+chlorimuron-ethyl 9 g/ha (POE) than other treatments. All the interactions were non-significant. Quizalofop 50 g/ha+chlorimuron @ 9 g/ha, imazethapyr @ 75 g/ha and pendimethalin @ 0.45 kg/ha can be used in both the planting methods i. e. flat as well as raised bed planting methods.

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Studies on harvest time residue of butachlor in soil, rice grain and straw

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The continuous use of butachlor on rice crop can cause its accumulation in rice grain, soil and straw, hence the present investigation was undertaken to determine the harvest time residues of butachlor in soil, rice and rice straw resulting from the continuous application of butachlor herbicide. A long term trial on weed control studies in rice-wheat system has been in progress since 1990-91 using butachlor applied @ 1.5 kg/ha. In 2004 and 2005, butachlor was sprayed after four days of transplanting of rice (cv. Narendra 359) and crop was harvested in November. The experiment was conducted in a randomized block design with three replications. At the time of harvest, samples of soil, rice grain and straw were collected from the herbicide treated plots. A 10 g sample of rice grain and soil and 5 g sample of straw were extracted with dichloromethane (2 x 20 ml) after shaking for an hour on a wrist action shaker. The contents were filtered through Whatman No. 42 filter paper and the filtrate was concentrated to about 20 ml. It was then partitioned with 20 ml of water. After partitioning, the dichloromethane layer was collected and anhydrous 2 g hot Na_2SO_4 was added therein for absorption of any water content. The solution was filtered out and the filtrate was concentrated to about 0.5 ml under reduced pressure. Thereafter, a silica gel column was prepared and after washing it with dichloromethane the sample was loaded on to the column. The sample was eluted with (90 : 10) dichloromethane-acetone mixture and evaporated under reduced pressure at 32±1°C. The residue was finally made up to 2 ml in the mobile phase. The reference standard of butachlor of 95.4% purity was obtained from M/s Herbicide India, Jaipur used for quantification, recovery and determination of the retention time of the herbicide. The soil, grain and straw samples were fortified with 100 ppm levels (1 ml) for assessing the per cent recovery. Samples were subjected to HPLC using (methanol : water v/v) mobile phase. The retention time of butachlor under the present experimental conditions was found to be 5.5 min. The mean recovery for soil, grain and straw for twp years was found 79, 80 and 82%, respectively. The minimum detection limit of the herbicide on the above HPLC system was 0.001 µg/g. The analysis revealed that no residues of butachlor were detectable at the time of harvest in soil, rice grain and in rice straw.

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Studies on residue of paraquat applied for weed control in potato

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Pre-emergence use of herbicides for controlling weeds in potato is of great importance. Potato (*Solanum tuberosum* L.) is one of the important commercial crops of the state. Weed infestation not only reduces the tuber yield but also affects the quality of potato tubers. In this experiment, paraquat at 0.18 and 0.36 kg/ha was applied 15 days after sowing (DAS). This herbicide gave good control of weeds in potato. To evaluate paraquat residues in potato, tubers were collected at harvest for estimation of residues. Estimation of paraquat in potato tuber was done spectro-photo-metrically with sensitivity of < 0.01 ppm. No residue of paraquat was found in potato tubers. Therefore, use of paraquat for weed control in potato at recommended dose was found safe.

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Growth and development of *Phalaris minor* Retz. and wheat (*Triticum aestivum* L.) as influenced by rice residue management techniques and weed control treatments

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Investigations were carried out to study the integrated effect of rice residue management techniques and weed control treatments on growth and development of *Phalaris minor* and wheat during *rabi* seasons of 2004-05 and 2005-06 at the experimental farm of Department of Agronomy, Punjab Agricultural University, Ludhiana, on loamy sand soil. Trial was conducted in split plot design with three replications. In main plots five rice residue management treatments i. e. no rice residue, surface application of 5, 6 and 7 t/ha of rice residues and incorporation (5 t/ha) were kept and in sub plots there were four weed control treatments viz., clodinafop 60 g/ha, sulfosulfuron 25 g/ha, mesosulfuron+iodosulfuron 12.0 g/ha and control (unweeded). The studies revealed that surface application of rice residues 6 and 7 t/ha significantly reduced the growth and development of *P. minor* as compared to incorporation and no rice residue treatments. Application of rice residue @ 7 t/ha also reduced the emergence of wheat seedlings. Grain yield of wheat was statistically similar in all rice residue management techniques. Application of clodinafop (5278 and 4758 kg/ha), sulfosulfuron (5392 and 5312 kg/ha) and mesosulfuron+iodosulfuron (5186 and 5115 kg/ha) were statistically similar with each other and recorded significantly higher grain yield of wheat than control (3711 and 3133 kg/ha) treatment during the first and second year, respectively, as growth and development of *P. minor* was significantly reduced in the herbicidal treatments as compared to control (unweeded) treatment.

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Bio-efficacy of herbicides under different planting techniques against weeds in wheat

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Field experiments were conducted at the experimental farm of Department of Agronomy, Punjab Agricultural University, Ludhiana, on loamy sand soil during ***rabi*** seasons of 2004-05 and 2005-06 to evaluate the bio-efficacy of herbicides for the control of *Phalaris minor* and broad leaf weeds in wheat with respect to different planting techniques. The experiment was conducted in split plot design with three replications. Five planting techniques i. e. conventional tillage, zero till sowing without stubbles, zero till sowing in standing stubbles, zero till sowing after partial burning and bed planting were kept in main plots and five weed control treatments i.e. clodinafop 60 g/ha, clodinafop 60 g fb 2, 4-D 0.5 kg/ha, sulfosulfuron 25 g/ha, mesosulfuron+iodosulfuron 12.0 g/ha and control (unweeded) were kept in sub-plots. *P. minor* as well as broad leaf weeds were significantly reduced and as a result significantly higher grain yield of wheat was recorded with zero till sowing in standing stubbles (4885 and 4637 kg/ha), zero till sowing after partial burning (4806 and 4586 kg/ha) and bed planting (4634 and 4383 kg/ha) than zero tillage without stubbles (4518 and 4238 kg/ha) and conventional tillage (4454 and 4156 kg/ha) treatments, during first and second years, respectively. Post-emergence application of clodinafop fb 2, 4-D, sulfosulfuron and mesosulfuron+iodosulfuron significantly reduced *P. minor* as well as broad leaf weeds, whereas clodinafop alone controlled *P. minor* only. Hence, significantly higher grain yield of wheat was observed under clodinafop fb 2, 4-D (5312 and 4783 kg/ha), sulfosulfuron (5373 and 5238 kg/ha) and mesosulfuron+iodosulfuron (5091 and 5023 kg/ha) than clodinafop alone (4607 and 4331 kg/ha) and control (2914 and 2629 kg/ha) treatments during first and second year, respectively.

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Performance and residual effects of mesosulfuron+iodosulfuron 3.6 WDG under variable moisture levels for control of *P. minor* in wheat

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Field study on the evaluation and residual effects of mesosulfuron+iodosulfuron for the control of weeds in wheat under varied moisture levels and soil types was conducted at the Research Farm of Department of Agronomy, Agromet and Forestry, PAU, Ludhiana during ***rabi*** season of 2005-06. The study revealed that all doses of mesosulfuron + iodosulfuron (12, 18 and 24 g/ha) provided an effective kill of weeds resulting in 100% reduction in dry matter accumulation by weeds as compared to unsprayed (control) treatment. All the herbicidal treatments were at par with respect to yield and yield attributes of wheat, irrespective of variable soil moisture levels present at the time of their application. Herbicides treated plots produced higher grain yield (116.3-117.3%) than unweeded crop. No residual effect of mesosulfuron+iodosulfuron applied at 12, 18 and 24 g/ha to wheat on succeeding crops of moong, cotton, bhindi and dhaincha was observed. However, growth and development at bajra and maize was adversary influenced by residual effects of the herbicide.

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Studies on the residual effects of herbicides applied during *rabi* season through bioassay

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Pot experiments were conducted on the experimental farm of the Department of Agronomy, Punjab Agricultural University during 2006-07 crop season to study the residual effects of wheat herbicides on succeeding maize, cotton, moong, mash, bajra, ricebean, muskmelon and bottlegourd. Pre-emergence application of trifluralin 1.2 kg/ha, post-emergence applications of clodinafop 60 g/ha, pinoxadin 40 g/ha, sulfosulfuron 25 g/ha, mesosulfuron+iodosulfuron 12 g/ha and sulfosulfuron+metsulfuron 30 g/ha were made in the second fortnight of December. Different test crops were sown without disturbing the soil in the third week of April. Ten viable seeds of bajra, moong, mash, cotton, maize and five for bottlegourd, muskmelon and ricebean per pot were sown. Experimental results indicated no residual effects of all the applied herbicides on cotton, moong, mash, ricebean, muskmelon and bottlegourd compared to untreated (control treatment). However, fresh weight of maize and bajra sown after the application of sulfosulfuron was found to be significantly lower compared to their sowing after the application of clodinafop, pinoxadin and trifluralin. The fresh weight per plant of maize raised under the residual effect of sulfosulfuron was found at par with mesosulfuron+iodosulfuron and sulfosulfuron+metsulfuron.

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Studies on cross resistance in *Phalaris minor* biotypes to wheat herbicides

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Pot experiments were conducted at the experimental farm of the Department of Agronomy during 2006-07 to find out the possibility of development of cross-resistance in *Phalaris minor*. Seeds of 30 biotypes of *P. minor* were collected from farmers' field who sprayed clodinafop or sulfosulfuron continuously or alternatively for several years to control *P. minor* in wheat. The seeds of these biotypes were sown in rows in small pots/rectangles and were exposed to pre-emergence application of trifluralin (Treflan 48 EC) 1.2 kg/ha and post-emergence applications of clodinafop (Topik 15 WP) 60 g/ha, sulfosulfuron (Leader 75 WG) 25 g/ha, pinoxadin (Axial 10 EC) 40 g/ha, mesosulfosulfuron+iodosulfuron (Atlantis 3.6 WDG) 12 g/ha and sulfosulfuron + metsulfuron (Total 75 WG) 30 g/ha. Pre-emergence application of trifluralin and post-emergence application of pinoxadin provided cent per cent control of all the biotypes of *P. minor* followed by sulfosulfuron+metsulfuron, mesosulfosulfuron+iodosulfuron, sulfosulfuron and clodinafop, respectively, with respect to production of fresh weight per pot, tillers per plant, panicles per plant and seeds per panicle of *P. minor*. Clodinafop was found less effective as compared to all other herbicides as significantly higher fresh weight per pot, tillers per plant, panicles per plant and seeds per panicle of *P. minor* were observed as compared to all other tried herbicides. Also differential growth behaviour for growth parameters among various biotypes was also observed.

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Isoproturon resistance in some populations of *Avena sterilis* from northern Greece

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Wild oats (*Avena sterilis*) is one of the most important weeds in the world. In Greece for instance it is the main weed in winter cereal crops. Isoproturon has been used to control it during several years, but from 1999 it has been unsuccessful in controlling this weed in some farms. Three putative resistant (PR) biotypes from Assizos, Florina and Kozinos (A, F and K) wheat cropping systems in Greece were compared to one isoproturon susceptible (S) population from Thermi (T). Petri dish assays used to calculate the EC_{50} of isoproturon yielded a value of around 700 mM for the three R biotype and 328 mM for the S biotype, with a resistant factor of 2.1. Dose-response assays were conducted with whole plants to determine ED_{50}. The resistance factor ($ED_{50}R/ED_{50}S$) was 2.8, 2.6 and 2.6 for biotypes A, F and K, respectively. The growth chamber bioassays conducted with fenoxaprop-p-ethyl and imazamethabenz-methyl indicated these herbicides were effective in controlling both putative resistant and the susceptible biotypes. These results confirm *A. sterilis* biotypes resistance to isoproturon and indicate that there is no multiple resistance in these populations to fenoxaprop and imazementhabenz. The study suggests that herbicides from other modes of action could be used to control this resistant biotype of *A. sterilis*.

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Bioefficacy of penoxsulam on weed control spectrum in transplanted rice

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Weeds are the major constraints in crop production especially in rice where it reduces the yield upto an extent of 15-45%. For the last many years, voluminous and high doses of herbicides like butachlor, thiobencarb and anilophos are used in transplanted rice. With the use of same herbicides, the problem of weed shift has manifested in this system. To avoid repetitive use of same herbicide, a new molecule penoxsulam was tested in the field experiment during 2005 to 2006 to control weeds in transplanted rice. Field experiment was conducted, having 10 treatments consisting of different doses and time of application of penoxsulam and other herbicides like butachlor and pretilachlor. The experiment was conducted in RBD with three replications. Penoxsulam applied as pre-emergence to weeds was found more effective in reducing the weed density as well as crop-weed competition as compared to early post-emergence during both the years. Penoxsulam was found more effective especially against *Echinochloa colona* and *Cyperus difformis* as compared to butachlor and pretilachlor, where it recorded lower weed dry matter. Penoxsulam applied at 20.0 and 22.5 g/ha as pre-emergence recorded higher weed control efficiency due to better effects on weeds. Highest grain yield was obtained with penoxsulam at 22.5 and 25 g/ha at 0-5 DAT during 2005 and 2006, respectively. Penoxsulam at 22.5 and 20.0 g/ha was better than both butachlor and pretilachlor. Weedy plot recorded 41 and 34% lower grain yield as compared to the treatment having highest grain yield during both the years. Based on two season studies it can be concluded that penoxsulam at 20-25 g/ha applied as pre-emergence and 22.5 g/ha applied as post-emergence effectively control major weeds in transplanted rice. Also, it had no phytotoxicity effect on rice crop.

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Azimsulfuron : an emerging herbicide for direct seeded rice

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The main driving force for rice production system in dry direct seeded rice (DSR) is weed management; the rising wage rates, scarcity of water, etc. are other major constraints. Notwithstanding the labour costs, weeding in rice under moist conditions is the last choice of agricultural labourers, which has given momentum to the herbicides for weed management in rice. The slow initial seedling establishment and growth of young rice seedlings are more susceptible to weed competition in direct sown wherein the grain yield losses may go upto 100%. Pre-emergence herbicides being used in DSR impart only partial control and are not effective against weeds like *Cyperus rotundus*. Thus, a new herbicide azimsulfuron was tested in DSR to evaluate its efficacy alone and tank-mix application with metsulfuron-methyl (MSM). Field experiment was conducted at GBPUAT, Pantnagar during ***kharif*** 2006 in a RBD with three replications of 10 treatments (azimsulfuron alone and tank mixed with MSM). Pendimethalin as pre-emergence followed by MSM was used as standard check. Application of azimsulfuron with MSM was found to be more effective against weeds at all stages. Azimsulfuron either alone or with MSM @ 30 g/ha recorded the comparable weed density as pendimethalin. The major grassy weeds *Leptochloa chinensis, Eragrostis japonica*, *Echinochloa colona* and *Echinochloa crus-galli*. Azimsulfuron was found effective against *Cyperus* spp. Azimsulfuron 30 g/ha with MSM 2 g/ha recorded the significantly higher yield (5.54 q/ha) compared to 25 g/ha alongwith MSM. Higher doses of azimsulfuron recorded the higher yield as compared to lower doses, however, the difference was non-significant between the different doses. Lower grain yield in azimsulfuron treated plot was mainly due to infestation of grassy weeds in the experimental plot. Since azimsulfuron was ineffective against the grassy weeds, but was effective against sedges and broad-leaved weeds. Temporary phytotoxicity was observed with azimsulfuron at initial stage, however, plants recovered within 15-20 days.

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Evaluation of penoxsulam for the control of weeds in transplanted rice

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A field experiment was conducted at the Research Farm of Rice Section, Punjab Agricultural University, Ludhiana in 2007 to evaluate the potency of penoxsulam applied at different doses and times against weeds in transplanted rice. Field was dominated by *Echinochloa crus-galli* and *Cyperus iria*. The experimental results revealed that penoxsulam 23 g/ha applied 12 days after transplanting (DAT) provided highest grain yield (7.95 t/ha) among all the treatments with maximum weed control efficiency of 92%. Penoxsulam reduced dry matter accumulation by weeds 12 DAT as compared to its early application 3 DAT and found more superior in terms of grain yield compared to its early application 3 DAT. The grain yield with the application of penoxsulam 23 g/ha 12 DAT increased to the tune of 19 and 137% over the application of butachlor 1.5 kg/ha and unweeded check, respectively. Hand weeding twice was found equally effective in reducing weed dry weight as butachlor 1.5 kg/ha and hence recorded statistically similar yield.

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Evaluation of carfentrazone in combination with different grassy herbicides for the control of complex weed flora in wheat

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A field experiment was conducted during three consecutive ***rabi*** seasons of 2004, 2005 and 2006 at the Agronomy Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar to evaluate the efficacy of carfentrazone as tank mixture or sequential application with grassy herbicides viz., clodinafop, fenoxaprop and sulfosulfuron for controlling the complex weed flora in wheat. All herbicidal treatments effectively controlled the weeds and gave significantly higher yield than the weedy check. Post-emergence application of fenoxaprop at 120 g/ha and clodinafop at 60 g/ha alone provided excellent control of *P. minor* Retz. and *A. ludoviciana* Dur., carfentrazone at 20 g/ha proved very effective against all broad leaf weeds. Sulfosulfuron at 25 g/ha provided control of grassy weeds and partial control (50%) of broad leaf weeds. Application of grassy herbicides and carfentrazone as tank mixture or their application in sequence after one week interval effectively controlled the complex weed flora and produced grain yield of wheat equal to weed free treatment. Although tank mixing of carfentrazone with these herbicides caused tip yellowing of wheat plants, but crop recovered within 8-10 days and this suppression did not translate into grain yield reduction. No antagonism between grassy herbicides and carfentrazone was observed.

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Studies on the effect of sulfosulfuron 75%+metsulfuron 5% WG on clodinafop resistant *Phalaris minor* in wheat

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To control isoproturon resistant biotypes of *P. minor*, alternate herbicides clodinafop-propargyl, fenoxaprop-P-ethyl and sulfosulfuron were recommended. These herbicides were readily accepted by the farmers and their use provided effective control of *P. minor* upto 2003. During 2004 and 2005, large number of complaints of poor efficacy of clodinafop was received from farmers' fields. Keeping this in view, a field study was undertaken during ***rabi*** 2006-07 at farmers field in village Chanarthal (Kurukshetra) where clodinafop-propargyl 15% WP was being used in wheat field continuously for four years. Seven treatments comprising ready mixture of sulfosulfuron 75%+metsulfuron-methyl 5% WG at 30+2 g/ha, mesosulfuron methyl 3%+iodosulfuron 0.6% WG (RM) at 12+2.4 g/ha, fenoxaprop-p-ethyl 10 % EC at 120 g/ha, clodinafop 15% WP at 60 and 120 g/ha were applied at 45 DAS of wheat and compared with untreated check. Sulfosulfuron+metsulfuron at 30+2 g/ha proved very effective against *P. minor* with 98.9% control followed by sulfosulfuron at 25 g/ha (92.3%) and mesosulfuron+iodosulfuron at 12+2.4 g/ha (91.4%). Clodinafop at 60 g/ha (x) and 120 g/ha (2x) and fenoxaprop at 120 g/ha were found to be least effective against *P. minor* providing 23.4, 27.6 and 21.5% control, respectively. Hence, putative clodinafop resistance *P. minor* was found highly sensitive to sulfosulfuron+ metsulfuron at 30.+2 g/ha. Similarly, highest grain yield (48.6 q/ha) was recorded with sulfosulfuron+metsulfuron at 30+2 g/ha followed by sulfosulfuron at 25 g/ha (46.3 q/ha). Among herbicidal treatments, minimum grain yield was recorded with clodinafop at 60 (x) and 120 g/ha (2x) and fenoxaprop at 120 g/ha by 30.6, 32.1 and 32.7 q/ha, respectively, which was almost similar to weedy check (27.8 q/ha).

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Evaluation of weeding devices for upland rice in North Eastern ghats of Orissa

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An experiment was conducted at Dry Land Research Farm, Phulbani during 1998-2000 ***kharif*** (three years) with eight treatments. Out of five weeders tested, Phulbani dryland weeder has registered the highest rice yield (37.14 q/ha), shown the highest cost : benefit ratio (1.86) as well as reduced the man power in weeding operation to a considerable extent per unit cropped area. Other advantages of this weeder are that it works as the best crust breaker, a potato and groundnut digger and it can be used as a very good garden tool. It can be concluded that the Phulbani dry land weeder which takes minimum labour compared to other weeders and saves 57% of labour as compared to hand weeding should be recommended for all the crops for weeding.

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Pyrazosulfuran-ethyl–an effective herbicide for direct seeded rice in South Cauvery Command Area

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Field trials were conducted at Zonal Agricultural Research Station, V. C. Farm Mandya under AICRIP on rice during ***kharif*** seasons of 2002 to 2004, to evaluate alternative herbicide for direct seeded rice with rice cultivar BR-2655 (135 days duration). The experimental soil was red sandy loam with pH of 6.8, O.C.% of 0.52, available N 278 kg/ha, Olesen P 23 kg/ha and 179 kg K_2O/ha. There were nine treatments viz., butachlor+safener (47.6 EC) applied 3 DAS at 1.0 kg/ha,butachlor+propanil (27.5 + 27.5 EW) 1.05 + 1.5 (10 DAS), Pyrazosulfuran-ethyl (5 WP) 0.002 (10 DAS), pyrazosulfuran-ethyl (5 WP) 0.025 (10 DAS), almix + 0.2% surfactant (20 WP) 0.004 (20 DAS), almix+0.2% surfactant (20 WP) 0.004 (25 DAS), hand weeding (20 and 40 DAS), pretilacholor+safaner (Sofit 30% EC) 0.40 kg/ha (3 DAS) and unweeded check. The treatments were replicated thrice in RBD design. Results indicated that use of pre-emergent herbicide pyrazosulfuran @ 0.025 kg/ha could be an alternative herbicide for direct seeded rice cultivation applied on 10th day after sowing. This was not only efficient but it was also economical with a B : C ratio of 1 : 7.46 as compared to hand weeding twice (1 : 1.79) and other herbicides (1 : 4.5). Thus, pyrazosulfuran could be used as an alternative herbicide for direct seeded rice in South Cauvery Command Area of Karnataka in addition to other recommended herbicides.

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Efficacy of PIH 2023, penoxsulam and azimsulfuron for post-emergence weed control in wet direct seeded rice

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In most of the South Asia, common practice of establishing rice in the rice-wheat system is through puddling followed by transplanting. Puddling helps in reducing water losses through percolation and controlling weeds by water stagnation in rice fields. But besides being costly, cumbersome and time consuming, it results in degradation of soil and other natural resources and subsequently poses difficulties in seedbed preparation for succeeding wheat crop in rotation. Direct seeding of rice (DSR) may be cost-effective and can give higher net returns because production costs are lower. However, appropriate water and weed management particularly during early growth stages are two key factors to achieve satisfactory yields under direct seeding. Hence, efforts were made at CCS Haryana Agricultural University Regional Research Station, Karnal during ***kharif*** 2006 and 2007 to evaluate some of promising herbicides for post-emergence (15 and 25 days after sowing–DAS) control of weeds in DSR under puddled and unpuddled conditions. PIH 2023 at 30 g/ha and penoxsulam 25 g/ha provided maximum control of weeds. Among different doses of azimsulfuron, the maximum control was obtained at 30 g/ha alone or in combination with metsulfuron. Addition of almix to fenoxaprop had antagonistic effect on weed control. Fenoxaprop had some phytotoxic effect on the crop. Pendimethalin applied at 7 DAS also proved highly phytotoxic to rice. Under unpuddled situations, the effective tillers due to clodinafop and metsulfuron were at par with weedy check and significantly lower than weed free treatment. Under both the situations, the maximum grain yield was obtained with PIH 2023 at 30 g/ha followed by penoxsulam 25 g/ha and then azimsulfuron 30 g/ha, which were at par with weed free treatment. In general, the efficacy of azimsulfuron was higher under puddled as compared to unpuddled conditions. Under unpuddled conditions during ***kharif*** 2007 also, PIH 2023 provided maximum control of grassy weeds particularly *Echinochloa crus-galli* followed by penoxsulam and azimsulfuron. Optimum dose of PIH 2023 and penoxsulam each was realized to be 25 g/ha. Azimsulfuron was not as good against *E. crus-galli* but excellent against broad leaf weeds and sedges including *Cyperus* spp. Azimsulfuron gave maximum control of *E. crus-galli* at 30 g/ha at 15 DAS and penoxsulam proved medium in its performance against all types of weeds. In general, application at 15 DAS was found better than 25 DAS in case of all the herbicides except PIH 2023 which performed almost similar against *E. crus-galli* when applied either at 25 DAS or 15 DAS.

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Pinoxaden-a new alternate herbicide for controlling *Phalaris minor* in wheat

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In rice-wheat rotations, *Phalaris minor* Retz. is a major problem in wheat cultivation. Due to continuous use of isoproturon over the last about two decades in this cropping system, resulted in evolution of resistant biotypes of *P. minor* in India. Pinoxaden is a novel grass active post-emergence from the chemical class phenylpyrazolin and effective against resistant biotypes; therefore, field experiments were conducted at Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana from 2003-04 to 2006-07, to evaluate efficacy of pinoxaden against isoproturon resistant *P. minor* in wheat. An experiment with seven treatments and four replications was laid out in randomized block design (RBD) during first three years. Application of pinoxaden after 30-35 days of sowing (DAS) of wheat provided efficient control of *P. minor* (91 to 100 %) and proved similar to the already recommended herbicide i.e. clodinafop. On an average of three years, bioefficacy of pinoxaden at 35 and 40 g/ha was found to be statistically similar with clodinafop at 60 g/ha with respect to yield and yield attributes and gave 91.8 and 97.5% higher wheat yield than unweeded (control), respectively. During ***rabi*** 2006-07, an experiment was planned at the Research Farm to compare pinoxaden at 40 g/ha with the other alternative herbicides like trifluralin, sulfosulfuron, clodinafop, mesosulfuron+iodosulfuron and sulfosulfuron+metsulfuron. Bioefficacy of pinoxaden at 40 g/ha was found to be statistically similar to all the other tested herbicides except clodinafop at 60 g/ha which was significantly inferior with respect to yield and yield attributes. Pinoxaden at 40 g/ha gave 51 and 106% higher wheat yield than clodinafop and unweeded (control), respectively. Bio-efficacy of pinoxaden at 40 g/ha in the adaptive trials over 46 locations in 12 districts of Punjab during 2006-07 was found similar to the already recommended herbicides i.e. sulfosulfuron at 25 g/ha and clodinafop at 60 g/ha herbicides and increased the wheat grain yield by 38.2% over unweeded (control). Bioassay studies conducted in pots after the application of pinoxaden to wheat indicated that growth of succeeding crops such as maize, cotton, bottle gourd, moong, mash, muskmelon, bajra and rice bean was not influenced due to the residual effect of this herbicide.

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Bioefficacy of orthosulfamuron alone and its tank mix combinations against weeds in transplanted rice

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Weed competition is the main factor for reducing yield of rice. Depending on intensity of weed infestation, losses in paddy yield may vary from 25-55% under transplanted conditions. Orthosulfamuron is a new herbicide for early post-emergency treatment in rice fields. Orthosulfamuron, an acetolactate synthase (ALS/AHAS) inhibitor was tested alone and as sand mix application with butachlor during ***kharif*** 2005 and 2006 to find out its efficacy against grasses, sedges and broad leaf weeds of transplanted crop of rice in order to provide wider options to the farmers for weed control in transplanted rice. The field experiment was conducted at the experimental area of Department of Agronomy, Punjab Agricultural University, Ludhiana, during ***Kharif*** 2005 and 2006. During 2005, the first experiment comprised 13 treatments of orthosulfamuron 50% WG at 35, 60, 75 and 120 g/ha through spray application at 3 and 12 days after transplanting were compared with butachlor 1500 g/ha. The second experiment consisted of 12 treatment combinations i.e. alone application of orthosulfamuron at 40, 60 and 75 g/ha tank mix application of orthosulfamuron 50% WG at 40, 60, 75 g/ha with butachlor 900 and 1250 g/ha each. During 2006, all the alone application treatments of orthosulfamuron and its sand mix application with butachlor were adjusted in one experiment. Orthosulfamuron when applied at 3 and 12 days after transplanting was found to be unsatisfactory as compared to recommended herbicide i.e. butachlor with respect to dry matter accumulation by weeds and production of seed yield of rice, however, higher rates of orthosulfamuron i.e. 120 and 150 g/ha resulted in significant reduction in dry matter accumulation by grassy weeds as compared to its lower doses i.e. 35 and 60 g/ha irrespective of its time of application. Tank mix combinations of orthosulfamuron with butachlor were found very effective for the control of heterogeneous weed flora in transplanted rice. All the applied herbicide treatments excluding application of orthosulfamuron at 35 g/ha, 3 DAT and its application at 35 and 60 g/ha, 12 DAT produced significantly higher seed yield of rice as compared to unweeded control treatments.

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Soil solarization and weed management

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Weed control by mechanical and cultural means has some limitations as they are laborious, while chemical means have environmental threat. Besides, these methods were employed only after the crop attained certain stage of growth, by this time the weed would have also grown sufficiently to cause damage to the crop. Hence, soil solarization, a preventive measure could be an efficient and non-hazardous option. Soil solarization is a method of heating the surface soil by using plastic sheets placed on moist soil to trap solar radiation thereby increasing the soil temperature. Plastic mulching in babycorn was found to be beneficial for getting significantly superior baby corn yield (12.6 t/ha) and green fodder yield (22.1 t/ha) as compared to rice straw mulch and unmulched treatments. WUE was also higher in polyethylene mulches as compared to other treatments. This better performance of baby corn in TPE mulch might be attributed to better weed control achieved in TPE mulch, this was indicated by lower weed density and weed dry weight as compared to rest of the treatments. Soil solarization with TPE 0.05 mm for 45 days recorded a significantly higher soil microbial biomass (896.5 μg/g) which was statistically similar to TPE 0.10 mm for 45 days. Significantly lower soil microbial biomass was recorded due to non solarized control plots. The increase in soil microbial biomass in treatments with TPE 0.05 and 0.10 mm for 30 and 40 days could be attributed to a selective survival of certain microorganisms and ultimately the burst out of population resulting in an enormous increase in soil microbial biomass. This could be attributed to deleterious effects of temperature on account of abrupt increase in soil temperature (53.3 to 55.1°C). Thin TPE recorded significantly lower total weed population. Higher soil temperature under thin TPE could be attributed to favourable properties such as higher transmission, lower reflection and absorption of solar radiation. This was owing to effect on weed reserve in soil. Soil solarization for 45 days had lower weed population as compared to 30 days of solarization. The higher heat dosage delivered for longer period by the 45 days solarization must have helped in bringing down the weed seed reserve of the soil.

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Direct and residual effect of soil covers on weed dynamics and productivity of cotton-wheat cropping system

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Due to decline in soil productivity and total factor productivity of most remunerative rice-wheat cropping system, cotton-wheat cropping system is being widely adopted in northern India. But the slow initial growth of cotton alongwith wider row spacing and adequate moisture availability faces severe competition of weeds, resulting in yield losses upto 75% depending on the nature and intensity of weeds. Pre-emergence application of dinitroaniline herbicides provides good control of weeds in cotton during initial stages of crop growth only in adequate moisture condition but new weed flushes in later stages are not controlled satisfactorily with the pre-emergence herbicides. The allelopathic effect of plant residues before cotton sowing, heating the surface soil by using plastic sheets placed on moist soil to trap solar radiation and efficacy of post-emergence application of herbicides could be used as important alternate option for weed management in cotton and their residual effect on succeeding wheat. The field experiment was conducted during ***kharif*** 2003 and ***rabi*** 2003-04 at New Delhi on sandy loam soil low in nitrogen, medium in phosphorus and potassium with 7.4 pH. Twelve treatments were tested in randomized block design and replicated thrice. Wheat and gram straw (4-6 t/ha) and transparent polyethylene sheets (0.05-0.10 mm thickness) were spread before the sowing of cotton cv. Pusa 8-6 on 15 May 2003. Post-emergence application of herbicides (quizalofop-ethyl 25 and @ 50 g/ha, glufosinate @ 500 g/ha and paraquat @ 500 g/ha) was made 30 DAS with knapsack sprayer fitted with flat fan nozzle and protected shield using 500 l of water per hectare. To evaluate the residual effect of treatments applied in cotton crop on succeeding wheat crop, the layout of the experiment was kept undisturbed and wheat variety HD 2329 was sown on 26 November 2003. Results revealed that transparent polyethylene (TPE) sheet of 0.05 and 0.10 mm thickness resulted in 100% control of all weeds during entire crop growth. Use of gram straw @ 6 t/ha provided the second best treatment in decreasing weed population to an extent of 44.19 % closely followed by the application of wheat straw @ 6 t/ha and quizalofop-ethyl @ 50 g/ha. The highest seed cotton yield was obtained with TPE 0.10 mm thickness due to better weed control. In succeeding wheat crop the highest grain yield (49.20 q/ha) was recorded in those plots where TPE was spread in cotton crop. Quizalofop-ethyl @ 25-50 g/ha application in cotton seemed to be persisted for a longer period than glufosinate (500 g/ha) and paraquat (500 g/ha), resulting in better weed control in succeeding wheat crop.

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Effect of planting pattern and straw management on herbicide persistence, productivity and quality of wheat (*Triticum aestivum*)

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A field experiment was conducted at Students' Research Farm, Punjab Agricultural University, Ludhiana during ***rabi*** season of 2006-07 to find out the effect of rice straw management techniques on yield of wheat as well as growth and development of weeds. Five planting patterns i. e. sowing in standing stubbles with Happy Seeder and zero till drill, zero till sowing after removing the stubbles, bed planting and conventional tillage were kept in main plot treatments and four weed control treatments i. e. sulfosulfuron 25 g/ha, mesosulfuron+iodosulfuron 12 g/ha, pinoxadin 40 g/ha and control in sub plots. Wheat sown in standing stubbles either with Happy Seeder or zero till drill and zero till sowing after removing the stubbles resulted in significant increase in grain yield of wheat as well as significant reduction in dry matter accumulation by weeds as compared to conventional method of wheat sowing and these treatments increased wheat grain yield by 19.6, 17.1 and 11.9% and 13.6, 11.3 and 6.4% than conventional method of sowing and bed-planting, respectively. Post-emergence application of sulfosulfuron 25 g/ha, mesosulfuron+iodosulfuron 12 g/ha and pinoxadin 40 g/ha significantly increased wheat grain yield than unweeded (control).

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Role of soil types and soil moisture levels on bioefficacy and persistence pattern of mesosulfuron+iodosulfuron for the control of *Phalaris minor* under pot study

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Growth and development of *Phalaris minor* with respect to plant height, number of leaves/plant, panicle length and dry matter per pot were found to be significantly higher on silty clay loam soils as compared to sandy loam and sandy soils. The differences due to variable soil moisture levels (field capacity and 70-80% of field capacity) at the time of herbicide application were found to be non significant. Application of mesosulfuron+iodosulfuron at 12, 18 and 24 g/ha resulted in significant reduction in dry matter accumulated by *P. minor* and other growth attributes of *P. minor* as compared to unweeded (control). Grain yield of wheat (g/pot) was significantly higher in silty clay loam soil. Residue determination of mesosulfuron+iodosulfuron at recommended (12.0 g/ha) and double the recommended dose on three soil types was conducted by HPCL technique. Residue in any soil type was not detected at application rate of 12 g/ha when analysis was done upto 80 days after spray; however, residues of mesosulfuron+iodosulfuron applied only at 24 g/ha were detected in sandy soil just after spraying.

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Persistence of clodinafop-propargyl in soil and wheat crop

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Persistence of clodinafop-propargyl (Topic, 15 WP), an herbicide for the control of *Phalaris minor* biotypes, was studied in soil and wheat crop (*Triticum aestivum* Linn.) at harvest following an application after 35 days of wheat sowing at 60 and 120 g/ha for two seasons of 2004-05 and 2005-06. Residues were estimated by high performance liquid chromatographic (HPLC) technique. Limit of determination in grain and straw was 0.5 and 1.0 µg/g, respectively. Harvest time residues in soil, wheat grain, and straw were found to be below detectable limits. Microbial studies revealed that analysis of soil samples collected before herbicide application and at harvest during the first and second season showed no significant effect of herbicide on microbial fauna.

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Comparative evaluation of metsulfuron methyl residues in field soil by chromatography (HPLC) and bioassay

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Metsulfuron-methyl is a low application rate sulfonylurea herbicide, being widely used to control broad-leaved weeds in wheat. Residue analysis was standardized both by chromatographic (HPLC) and bioassay techniques. Field experiment was carried out with wheat (variety HD-2328) in the research fields of Agronomy Division, IARI. The herbicide was sprayed at different rates (4, 8 and 12 g/ha) at 28 DAS. The soil samples from 0-15 cm were collected from field and extracted for residue analysis at different intervals. Residue analysis of metsulfuron methyl by lentil seed bioassay technique was also carried out in the field soil. The comparison of both the techniques showed that bioassay was more sensitive technique. Bioassay technique could detect the residue upto 30 days in surface soil, while with HPLC residues were non detectable on 15th day. Residues of metsulfuron could also be extracted from 30 days soil samples, when lentil seeds were germinated in this soil, although they were not quantitatively equal to that of bioassay technique. At harvest time, sub surface soil (15-30 cm) was also analyzed by bioassay technique and residues at a level of 0.02 ìg/kg were detected, which were non-extractable by solvent extraction method. The studies indicated that non-extractable residues could be released by germinating plants making the bioassay technique more sensitive. The half-life of metsulfuron in field soil as detected by HPLC and bioassay was 7.45 and 17.1 days, respectively. At harvest time the residues of metsulfuron-methyl could be detected in sub-surface soil (15-30 cm) by bioassay indicating its mobility to sub-surface soil.

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HPLC analysis of harvest soil residues of sulfosulfuron and metsulfuron-methyl after bioassy

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Sulfosulfuron and metsulfuron-methyl are sulfonylurea herbicides used in wheat crop for the control of grassy and broad leaved weeds, respectively. The phytotoxicity to sensitive rotational crops by these two herbicides has been reported by many workers. The phytotoxicity may be due to parent compound or some degradation products (metabolites). Also our earlier studies indicated that non-extractable herbicide residues in soil could be released by germinating plants, making the bioassay technique more sensitive technique. If such soil is extracted at the time of seedling germination, the residues could be extracted and detected by HPLC as well. In view of this, a field experiment of wheat crop with these herbicides was taken up in Agronomy Division of IARI, New Delhi. Analysis of harvest soil was carried out by HPLC, but residues for both the herbicides were below detectable limits. Bioassy of metsulfuron and sulfosulfuron treated (harvest) surface soil was also carried out using mustard and oat, respectively. Extraction and HPLC analysis of soil, right at the time of germination, was also carried out in search of the released residues, if any. Results showed no phytotoxicity to the test plants in bioassay. HPLC analysis of this soil also showed residues below detectable limits. Thus, the study indicates towards the mobility of both the herbicides into deeper layer. Phytotoxicity observed in the next crop may be due to residues in sub-surface soil, which are available after various agronomical processes. Hence, sub surface soil must be analysed for mobile residues.

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Bio-control initiatives for *Parthenium hysterophorus*–an alien invasive weed in North Western Himalayas of India

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A study ws conducted in the Division of Agronomy, SKUAST-Jammu during the period starting from June 2000 to December 2005 to evaluate the effect of biological agents for managing *Parthenium hysterophorus* in North Western hills of India. *Zygogramma bicolorata*–a defoliating beetle was introduced in sub-tropical areas of Jammu and Kashmir to control parthenium plants, keeping in view that this part of the state has no acreage under sunflower crop (the alternate host for beetle) and it has been observed that it took six-years for the beetle population to grow sufficient enough to affect parthenium foliage. Also it has been found that 2-3 pairs of beetles could completely defoliate 4-5 fully grown parthenium plants per week. These beetles were found to feed voraciously from July to September and have rendered a tremendous help in controlling this weed in and around municipal areas of this part of the state. Moreover, the beetle has been found to remain in hibernation during the winter months in soil, particularly where the land is low lying and soil is relatively coarse with adequate moisture regimes. This was ascertained as the probable survival mechanism of the beetle during the slack period. On an average 2-3 beetle pupae were found per kg of soil samples from these areas. Besides, *Cassia tora* and *Senna alexandrina* either growing in wild or introduced in this area to the tune of 3 trees/bushes /sq m have been found to reduce the parthenium population to almost negligible levels. These species have picked up a lot of acceptance with farmers of Jammu region and in the just concluded rainy season a considerable area has come under these plants. *Cannabis sativa* population was also observed to suppress the weed regeneration considerably, especially during the rainy season which was substantiated by the *Cannabis* root and shoot extract studies on germination of parthenium.

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Effect of 2, 4-dichloro phenoxy acetic acid on soil micro flora

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A field experiment was conducted with five levels of 2,4-D (0, 0.5, 1.0 , 2.0 and 4.0 kg/ha) to study the persistence of 2, 4-dichlorophenoxy acetic acid in wet land paddy and consequent changes in population of microorganisms in the soil system. The soil of the experimental site was sandy loam in texture, riverine alluvial having pH 5.15 and organic carbon 0.9%. Soil residues at 0, 1, 3, 6, 9 and 15 days after spraying were estimated by the colorimetric procedure and that of 30 and 60 days were analysed by gas chromatographic technique. For studying the effect of 2, 4-D on the population of soil bacteria and fungi, soil samples were taken from the treatments at 3, 6, 15 and 30 DAT. Quantitative analysis of soil micro flora was carried out by serial dilution technique. Changes in population of micro flora due to different rates of application of 2,4-D (percentage increase/decrease over hand weeded control) were worked out. The data showed that application of 2,4-D at the rate of 0.5, 1.0 and 2.0 kg/ha did not result in any detectable quantity of residues beyond nine days after spraying. At the rate of application of 4.0 kg/ha, quantity of 2,4-D residue persisted in the soil at 9 ,15 and 30 DAT was 0.202, 0.021 and 0.001 ppm, respectively, and the residues were not detectable at 60 DAT. Studies on soil micro flora revealed that fungi were benefited by 2,4-D application, whereas the herbicide had a negative effect on the population of soil bacteria. The magnitude of change increased with rate of application of 2,4-D and the change was maximum at 6 DAT in all the treatments. The percentage decline in bacterial population at this sampling time ranged from 61.9 to 89.5% depending on the rate of application. However, at 30 days after spraying there was an increase in the bacterial population irrespective of the level of application of the herbicide. The change in population of fungi in the treatments at 6 DAT ranged from +344% to +615% over control. This variation showed a decrease with the advancement of time, the range being +7.22 to +29.9% at 30 DAT. Attainment of nearly normal level of the population of fungi and bacteria by 30 DAT could be attributed to the dissipation of 2,4-D residues from the soil.

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Production and weed control of sunflower-bell pepper crop sequence in soil solarization with moisture regimes, time of FYM application and duration

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A field experiment was conducted for two consecutive years (2003 and 2004) to study the effect of soil solarization with moisture regimes, time of FYM application and duration of solarization on weed dynamics and yield of sunflower-bell pepper crop sequence at UAS, Bangalore under irrigated conditions. The experiment consisted of solarization during March–May followed by sunflower and bell pepper crop sequence and has 14 treatments viz. three moisture regimes (FC, 50% FC and control-dry), two timings of FYM application (before and after solarization) and two duration of solarization (45 and 60 days) with a non-solarized weedy check and two hand weeding treatments replicated thrice in a randomized complete block design. After harvest of sunflower, land was prepared with shallow digging and each plot was divided into two to study the residual effect of solarization. These were super imposed with one hand weeding and unweeded control treatments. Soil solarization for 60 days with irrigation upto FC and FYM application before solarization recorded significantly higher sunflower seed yield (32.64 q/ha) followed by 45 days solarization (32.52 q/ha) than non-solarized weedy check (14.70 q/ha) and two hand weeding (24.74 q/ha) treatments, respectively. Significantly higher fruit yield in bell pepper was recorded in residual effect of 60 days solarization with irrigation upto FC and application of FYM after solarization (23.67 t/ha), which was on par with all the solarized treatments with irrigation up to FC. Fruit yield was significantly lower with non-solarized weedy check (9.69 t/ha) compared to all other treatments. Weed count and dry weight at harvest in sunflower were significantly lower with two hand weedings (39.2/m^2 and 4.75 g/0.25 m^2) followed by soil solarization with irrigation upto FC. Significantly higher number and weight of weeds were noticed in non-solarized weedy check (283.3/m^2 and 32.80 g/0.25 m^2). In bell pepper, non-solarized weedy check recorded significantly higher total number and weight of weeds (161.5/m^2 and 47.28 g/0.25 m^2) over other treatments. It was inferred from the above study, that application of 10 t/ha farm yard manure before solarization for 45-60 days with irrigation upto field capacity was effective in reducing the weed menace and improving the productivity of sunflower-bell pepper crop sequence.

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Persistence of sulfosulfuron applied in wheat on succeeding crop of sorghum

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To study the effect of irrigation frequency on residual behaviour of sulfosulfuron applied in wheat on succeeding sorghum crop grown in rotation, field experiment was conducted during 2003 and 2004 in the Agronomy Research Area of CCS Haryana Agricultural University, Hisar. The residual effects were assessed by bioassay studies on sorghum. Experiment was conducted in split plot design with 3, 4 and 5 irrigations in the main plots and weed control treatments (sulfosulfuron 0, 25, 50 g/ha and weed free). After harvest of wheat crop, sorghum crop was planted after slight disking without disturbing the original layout. Sulfosulfuron applied in wheat was observed to persist even after 150 days after its application and its residues in the soil medium were found to be phytotoxic to succeeding crop of sorghum. When sorghum was grown in the field after harvest of wheat crop treated with 25 and 50 g/ha of sulfosulfuron (after about 150 days of sulfosulfuron application), the various growth parameters of sorghum viz., plant population, plant height, number of leaves per plant, dry shoot and root weight and fodder yield were significantly reduced. The maximum reduction in growth as well as in fodder yield was at higher concentration of sulfosulfuron. In comparison to untreated control, 50 g sulfosulfuron applied in wheat reduced plant height, dry shoot and root weight per plant of sorghum upto an extent of 56, 50, 70 and 57, 51, 71% in the first and second year, respectively (recorded at 60 DAS). A similar trend was observed in terms of fodder yield also, which recorded 73 and 75% reduction with 50 g sulfosulfuron as compared to untreated control in the first and second year of investigations, respectively. The residual effect of sulfosulfuron on sorghum was not found to be mediated by irrigation frequency. Neither the growth parameters nor the fodder yield of sorghum were affected significantly by number of irrigations applied in wheat. Therefore, it can be concluded that increasing irrigation frequencies neither helped in degradation nor in leaching of sulfosulfuron and sorghum should not be planted in rotation with wheat where sulfosulfuron has been applied to wheat.

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Repetitive use of transparent polyethylene for soil solarization in groundnut-bell pepper sequence

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A field experiment was carried out during 2004 and 2005 at Agronomy Field Unit, Main Research Station, University of Agricultural Sciences, Bangalore to work out the economics of soil solarization on break even basis with different thickness of polyethylene in groundnut-bell pepper crop sequence. The study involved two thickness of transparent polyethylene (TPE) (0.05 and 0.10 mm) covered once, twice and thrice in the same season for 45 days duration, weedy check and weed free throughout, replicated thrice in a randomized complete block design. The results indicated that among the solarized treatments, significantly higher pod yield of groundnut and fruit yield of bell pepper was registered with TPE 0.05 mm twice (23.6 q/ha and 15.1 t/ha, respectively) followed by TPE 0.05 mm once (22.7 q/ha and 12.0 t/ha, respectively) and TPE 0.10 mm twice (21.7 q/ha and 12.6 t/ha, respectively). Similarly, growth attributes viz., leaf area/plant and dry matter accumulation/ plant and yield attributes viz., number of pods/plant (23.0 to 22.1) and number of fruits/plant (6.4 to 5.3) were also superior with these treatments. Significantly lower number of weeds and weed dry weight were recorded with TPE 0.05 mm twice in both groundnut and sequence crop of bell pepper. Repetitive use of TPE 0.05 mm for two times in the same season recorded higher gross (Rs. 1,88,8287/ha), net income (Rs. 1,39,9547/ha) and B : C ratio (3.86) followed by use of TPE 0.05 mm for three times and TPE 0.10 mm for two times continuously in the same season.

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Weed dynamics, growth and yield of french bean as influenced by residual effect of soil solarization, sources and time of manure application

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A field experiment was conducted during 2003 and 2004 to study the residual effect of soil solarization, sources and time of manure application on weed dynamics, growth and yield of french bean at the Agronomy Field Unit, Main Research Station, University of Agricultural Sciences, Bangalore. The experiment consisted of 13 treatments for the first crop of sweet corn viz. application of organic manures before soil solarization for 45 days (Farm yard manure, poultry manure, compost and vermicompost), application of organic manures after soil solarization for 45 days, application of organic manures without soil solarization and a non-solarized check with no organic manures. Two weeding treatments (one hand weeding at 18 DAS and no-weeding) were superimposed to each treatment to study the residual effect on french bean. The experiment was carried out in factorial randomized complete block design with three replications. The results indicated significantly higher green pod yield of french bean with the application of poultry manure before solarization (12.3 t/ha) as compared to non-solarized treatments but it was on par with the solarized treatments. The growth parameters viz. number of branches per plant (5.4) and leaf area (382.9 cm/plant) were superior with the application of poultry manure before solarization. Among the weeding treatments, one hand weeding recorded significantly higher green pod yield (10.4 t/ha), number of branches per plant and leaf area over no weeding. Significantly higher total number of weeds (36.0/m^2) was observed with the application of compost without solarization, while significantly higher weed dry weight of 4.43 g/0.25 m^2 was registered with the application of FYM without solarization at harvest. Among the weeding treatments, one hand weeding recorded significantly lower weed count and weed dry weight at harvest.

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Effect of irrigation and metsulfuron-methyl on soil microbes in wheat (*Triticum aestivum*) field and residual effect on succeeding maize (*Zea mays*)

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A field experiment was conducted during the *rabi* season of 2004-05 at the Agronomy Research Farm of CCS Haryana Agricultural University, Hisar to study the effect of irrigation and metsulfuron-methyl on status of microbes in wheat field and residual effect of metsulfuron on succeeding maize crop. The soil was sandy loam; low in organic carbon (0.43%) and available nitrogen (185 kg N/ha); medium in available phosphorus (16 kg/ha P_2O_5); high in available potassium (341 kg/ha K_2O) and alkaline in reaction (pH 7.9). The experiment was laid out in split plot design with four replications. The treatments consisted of three irrigation levels viz., two irrigations at 22 and 65 DAS, four irrigations at 22, 45, 85 and 105 DAS, and six irrigations at 22, 45, 65, 85, 105 and 120 DAS in main plots and three metsulfuron levels viz., 2.0, 4.0 and 8.0 g/ha with untreated control (weed free) in sub-plots. The microbial population (total bacteria, fungi and Azotobacter) in wheat field decreased with increased concentration of the herbicide with lowest microbial population with 8 g/ha of metsulfuron for all microbes. The adverse effect on microbial population continued upto 15, 30 and 45 days after treatment (DAT) at 2, 4 and 8 g/ha of metsulfuron, respectively. Higher doses of herbicide produced more adverse effect on microbial population than lower doses. At 75 DAT, adverse effects of all doses of metsulfuron became negligible and microbial population in metsulfuron treated plots reached equal to that of untreated check. Different doses of metsulfuron and irrigation levels applied in wheat did not affect the plant population and various growth indices like number of leaves/plant, dry matter accumulation/plant, total fresh weight, total dry weight and shoot length of succeeding maize crop. Also, no visual toxicity on maize was observed due to different doses of metsulfuron applied in wheat under different irrigation levels.

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Effect of sulfonylureas on soil microbes and succeeding crops grown in rotation with wheat

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Sulfonylureas viz., chlorsulfuron at 30 and 60 g/ha, sulfosulfuron at 25 and 50 g/ha, metsulfuron at 4 and 8 g/ha and mesosulfuron+iodosulfuron (Atlantis) at 12+2.4 and 24+4.8 g/ha were applied in wheat at 35 DAS. The yield attributes (effective tillers, length of earhead, number of grains per earhead and 1000-grain weight) and grain yield of wheat were similar at all herbicidal treatments. The residual effect of sulfonylureas on succeeding sorghum and cotton crops was also found negligible. All growth parameters like number of leaves per plant, shoot length and dry matter accumulation per plant were non-significantly affected by all herbicidal treatments applied in wheat. In case of soil microbes, total bacterial population and *Azotobacter* population in wheat decreased significantly after 15 days of herbicides application and effects of herbicides on these microbes remained only upto 45 DAT. At the time of harvest, the population of these microbes reached to normal level as in case of untreated check.

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Impact of global warming on weeds and weed management

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In coming years, we have to produce more food, fibre and other commodities to cope with increasing population under diminishing per capita available land and water and degrading water resources and expanding biotic stresses. Current (380 mmol/mol) and projected increase in Co_2 concentration (600 mmol/mol) by the end of 21st Century in the atmosphere, as well as potential changes in temperature and precipitation, may have important consequences for crop losses due to weeds. The increased temperature and aridity are expected to alter the distribution and impact of weeds. Plant responses to climate change are not uniform and thus there will be winners and loosers. For the most important species on a worldwide basis, crops have predominantly C_3 photo synthetic metabolism and weeds disproportionally have C_4 metabolism. Among the 18 most troublesome weeds in the world, 14 are C_4, whereas of the 86 plant species that supply most of the world's food, only 5 are C_4 species. Various studies have shown that the growth of plants with the C_3, photosynthetic pathway tends to be stimulated more by Co_2 enrichment than is the growth of C_4 plants. Therefore, the future increase in the atmospheric Co_2 concentration might increase the competitive impact of C_3 weeds in C_4 crops while decreasing the impact of C_4 weeds in C_3, crops. However, under high temperature and water stress conditions, C_4 plants may exhibit significant growth increase in response to Co_2 enrichment. It has been observed that growth enhancement in response to Co_2 enrichment was greater in soybean (C_3) than in C_4 grassy weeds *viz., Echinochloa crus-galli, Eleusine indica* and *Digitaria ciliaris.* Similarly in rice (C_3), elevated Co_2 alone enhanced the crop competitiveness against *E. glabrescens,* but simultaneous increase in Co_2 and temperature favoured *E. glabrescens.* The growth, development and reproduction of most troublesome weed *Parthenium hysterophorus* have been found to increase in elevated Co_2 conditions. Increasing atmospheric Co_2 and associated changes in climate have the potential to directly affect weed physiology and crop-weed interactions *vis-a-vis* their response to weed control measures. The efficacy of herbicides is greatly influenced by environmental variables such as temperature, soil moisture and atmospheric humidity. Decreasing stomatal conductance with increased Co_2 could reduce the uptake of both soil and foliar applied herbicides. Climate change also alters the efficacy of biocontrol agents by changing the growth, development and reproduction of target weed. Increased root and rhizome growth particularly in perennial weeds due to elevated Co_2 may make the mechanical weed control more difficult