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Spread, menace and management of *Parthenium*

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ABSTRACT

Parthenium hysterophorus is an aggressive annual herbaceous plant, native to the tropical America. It is now widely distributed in a number of tropical and sub-tropical countries threatening natural ecosystems, agro-ecosystems and biodiversity worldwide. It has been considered a great cause of skin allergy in mankind and animals too in many countries around the globe. Parthenium has achieved major weed status in India and Australia and posing lurking threat to many African and South–Asian countries. Earlier, it was not considered a major threat to agricultural crops in India and other countires, but now, all types of crops are infested with the weed in India. The infestation of this weed causes yield losses up to 40% in several crops and reduces forage production up to 90%. The rapid spread of *Parthenium* in India would be a bigger risk to the expansion and sustainable production of many crops, orhcards and grassland ecosystems in protected forests. Various management approaches namely cultural, mechanical, chemical and biological have been used to minimize losses caused by this weed, but most of these approaches are ineffective and suffer from one or other limitations. Although management using herbicides and exotic bioagents *Zygogramma bicolorata* for biological control has been found to contribute effectively to suppress *Parthenium* in India, nevertheless, the weed remains a significant problem. Integrated Parthenium Management is advoated to fight against this invincible weed.Hence, an attempt has been made to review its current spread, impact on agriculture, human and animal health and management in context to world in general and India in particular.

Key words: Distribution, Infestation, Integrated management, Menace, *Parthenium*, Spread

The genus name *Parthenium* is derived from the Latin word *'parthenice'* a reference to the plant now known as *Tanacetum parthenium* (L.) Bernh. or 'feverfew'. the species name *'hysterophorus'* was derived from the Greek word*'hystera'* (womb) and *'phoros'* (bearing), referring to the prolific seeding habit of the plant (Parsons and Cuthbertson 1992). *Parthenium hysterophorus* L., globally known as feverfew, ragweed or *Parthenium* is a weed of world significance. It is most popularly known as 'congress grass' throughout India while in Hindi speaking belt known by the popular name of 'gajarghas'(carrot grass) besides vernacularly called as 'kadvighas' [bitter grass], or 'safed topi' [white top]. It is one of the most aggressive herbaceous weeds of the family Asteraceae. It is an annual short lived herbaceous plant that invades preferably vacant land, disturbed sites, road sides, railway tracks sides, wastelands, water courses, agricultural crops *etc*. It degrades natural ecosystems by reducing biodiversity (Holm *et al*. 1997) and can cause serious allergic reactions in man and animals (Lonkar *et al*. 1974, Chippendale and Panetta 1994). In Australia, it is a significant problem in rangelands (Haseler 1976). In India, it has invaded almost all types of crops and has become a serious threat for agricultural production. In spite of its non-tropical origin, it has now naturalized in several tropical and subtropical parts of the world under a wide range of environmental conditions. The weed causes immeasurable ecological and agricultural losses each year. It is spreading rapidly in Australia, many African, Caribbean and Asian countries and has become a serious concern of the government and public. The weed has great potential to spread into other new countries in the world.

The problem of *Parthenium* is particularly serious in rain-fed ecosystem and in non-cropped situations. Earlier, it was not considered a problem in agro, pasture and forest ecosystems but, at present many forests and national parks world over are severely infested with *Parthenium* threatening forest biodiversity and availability of palatable grasses to herbivores. The spread and infestation of *Parthenium* are severe in some of the countries like Australia, South Africa, Ethiopia, India and Pakistan, In India, the weed is a serious problem in states like, Andhra Pradesh, Bihar, Haryana,Karnataka, Madhya Pradesh. Tamil Nadu and Uttar Pradesh.

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Parthenium is regarded as one of the worst weeds because of its immense capacity of reproduction and ability to thrive in varied climatic conditions, to spread fast due to light and floatable tiny seeds, impact upon human health and environment. These attributes make this plant an invincible weed. Ever since, *Parthenium* has become a serious problem, efforts are being made globally to use different management approaches to contain this weed, but none of single method has been found effective due to its own limitations. Therefore, Integrated *Parthenium* Management (IPM) approach has been considered the only most effective solution to suppress the weeds below the economic threshold level. This review presents the available information on its distribution, spread, menace and managment in different agro-ecosystems, with various prevalent methods in context to world in general and India in particular. Such information would facilitate farmers, municipalities and forest managers, and weed scientists of *Parthenium* suffering countries to understand its biological attributes, spread, menace and to take appropriate measures to manage this most problematic weed.

Biological attributes responsible for *Parthenium* dominance

Parthenium is an annual herb with a deep tap root and an erect main stem that becomes woody with age having high cellulose content (Jaun *et al.* 2008 Kaur *et al.* 2014). A single plant produces many branches and eventually achieve an average height of 1.5 meter but in suitable conditions may achieve height up to 2.5 meter. Plant completes its one generation within 15 to 18 weeks and may complete 4 to 5 overlapping generations in a year depending on the climatic conditions of the area which may vary place to place and country to country. The plant has unique characteristics of achieving 'rosette' form in absence of water when after germination and achieving little growth, development become restricted, gradually leaves become thick and plant remain attached to ground. Such plants may grow normally on availability of water to produce seeds. This character makes this weed to sustain in high and low temperature regime and negligible water availability. Seeds maturation occur within two weeks of flowering and may continue even after the complete senescence of leaves. White (1994) concluded that *Parthenium* seeds may survive between 4 to 6 years. Navie *et al.* (1996) also found that buried seeds can survive for more than a year on upper surface and up to 6 years in the lower layers of soil.

Flowers are white to creamy-white in colour and are star-shaped, produced on top of the upper branches in clusters. Flowers have five petal-like ray florets, each bearing a single seed (Kohli *et al.* 2006), however, in its native range it may have yellow flowers in South American race (Dale 1981). Thus, single flower bear 5 seeds which are narrow, flattened and dark brown to black in color with wing like appendages. Seeds are 2 mm long and difficult to see by the naked eye. A single *Parthenium* plant may produce up to 25,000 seeds, leading huge seed bank in the soil. Seeds are so light that they are easily carried away up to long distance with the wind (Sushilkumar 2005). A large number of seeds fall directly onto water from the weed grown on the bank of water channels made for irrigation purpose and are carried directly to crop fields. It is one of the major factors contibuting infestation in crop fields directly. There may be up to 400 million seeds/ha on the surface soil (Joshi 1991). The seeds spread via vehicles, farm machinery, animals, pasture and crop seed lots, stock fodder/feed, wind, humans, mud adhering to vehicles, and moving water (Chippendale and Panetta 1994).

There is no seed dormancy in *Parthenium*. The seeds normally germinate with the availability of moisture. Maximum, optimum, and minimum temperatures for seed germination are 30-34, 22-25 and 12-15 °C, respectively. Maximum germination occurs at available soil moisture between 40 and 60% (Tamado *et al.* 2002). Naidu *et al.* (2007) kept fresh seeds of *Parthenium* in nylon net bags and subjected to running water for different durations of time *i.e.* 0 'hour (fresh seeds), 4 hours, 8, hours 24 hours, 28 hours, 32 hours and 48 hours. The germination was tested on filter paper in Petridishes and in sandy and clayey soils in pots. They found that per cent germination increased with increased duration of time under water flow and the seeds germinated within the nylon bags after 48 hours of running water treatment. The per cent germination was enhanced due to the removal of toxicants from the seed by running water. They concluded that germination of *Parthenium* seeds depends on sufficient rain to leach germination inhibitors from the seed. In India, good germination and growth of this weed occurs where the annual rainfall is greater than 600 mm, however, germination and growth is best having rainfall between 1000 to 1200 mm. The growth of *Parthenium* weed was restricted in saline and waterlogged soils in Pakistan (Marwat *et al.* 2010). Although *Parthenium* is capable of growing in most soil types of India, it is most dominant in alkaline, clay loam soils. But, Naidu *et al.* (2007) found that germination per cent of fresh seeds was higher in sandy soil (76%) than in clayey soil (5%) probably because of the leaching out of toxicant easily in the sandy soil. In Australia, Naive *et al.* (1996) found most favourable areas for *Parthenium* seed germination having an annual summer rainfall of more than 500 mm in a wide variety of other soils, from sandy loams to clay loams.

Parthenium can grow over a wide range of moisture and temperature conditions but requires high soil moisture for seed germination (Tamado *et al.* 2002). Its low photorespiration under arid conditions, photo- and thermo-insensitivity, C3/C4 intermediate mechanism, more biomass production at elevated atmospheric CO_2 concentrations as compared to the normal CO_2 concentration in a rapidly changing climate make it more invasive (Pandey *et al.* 2003, Naidu and Paroha 2008, Tang *et al.* 2009, McConnachie *et al.* 2011, Shabbir 2012 Naidu 2013). Naidu and Murthy (2014) discussed that invasive weeds like *Lantana* and *Parthenium* may become more aggressive under climate change especially due to increases in atmospheric CO_2. Growth at elevated CO_2 would result in anatomical, morphological and physiological changes that could influence herbicidal uptake rates, besides translocation and overall effectiveness.

Origin and spread of *Parthenium*

Parthenium is native to the area surrounding the Gulf of Mexico, Central America, Southern North America, West Indies, and Central South America (Navie 2003). About 20 countries are considered in its native range from where it has introduced into other 34 countries (Adkin and Shabbir 2014) around the globe, including major continents except Europe and many islands. It has now naturalized in several tropical and subtropical parts of the world. *Parthenium* is one of the most troublesome weeds and figures among the list of invasive species (GISD 2014). It has spread between countries across the border mainly by the movement of contaminated grain for human or cattle feed or by vehicles and wind.

Australia has been considered second most *Parthenium* affected country after India. First introduction in Australia was reported in 1950 (Parsons and Cuthbertson 1992), while second and more substantial introduction occurred in 1958 near Clermont in central Queensland as a contaminant of a pasture grass seed lot imported from Texas, United States (Haseler 1976). By 1994, it had invaded about 17 million ha of prime grazing pastures in Central Queensland (Chippendale and Panetta 1994), which extended to about 60 million ha by 2012 (Commonwealth of Australia 2012). The loss of pasture was estimated abut $109 million per year (Adamson 1996). International spread of *Parthenium* in the past 2-3 decades has been rapid, which indicates that *Parthenium* weed is still capable to spread into many other countries in near future, especially those in West Africa, South-East Asia and Eastern Europe and other parts of the world with a suitable climate (Nigatu *et al.* 2010, Adkin and Shabbir 2014). Holm *et al.* (1977) did not categorized this weed among the top 10 weeds of the world which reflected that by that time it had not become a problematic weed in the world, however after twenty years of publication of this book, *Parthenium* has become one of the seven most damaging weeds of the world (Evans 1997), because it had spread fast and extensively in many countries of the world.

Another severely affected region is Eastern Africa, with Ethiopia being one of the most emerging affected countries. In Ethiopia, *Parthenium* has become a serious problem in grazing and cropping lands and is thought to have arrived into the country as a food grain contaminant in a USAID programme in about 1980 (Tamado *et al.* 2002, McConnachie *et al.* 2011). In China, *Parthenium* illustrates with evidence from nuclear and chloroplast DNA that multiple introductions were responsible for subsequent invasions in China (Tang *et al.* 2009) and about eight provinces were at an alarming rate in near future (Naive *et al.* 2010).

India has become one of the most *Parthenium* affected countries in the world as this weed is occurring in all of her states and presenting a major problem in many those states that have large areas of non-cropped and pastures rain-fed land (Sushilkumar and Varsheny 2010, Sushilkumar 2012). It was surmised that *Parthenium* possibly got entry from USA through the imported food grains (Vertak 1968) or through the cereals obtained for experimental purpose (Lonkar *et al.* 1974). In most of the publications, first occurrence of *Parthenium* in India has been believed to be in 1955, when it was first noticed by a retired horticulturist, Prof. Paranjape and later on described by Rao (1956). However, some reports traced its history of occurrence about one and half century old (Roxburghi 1914, Maiti 1983, Dam *et al.* 1993). Its presence in India before 1955 got further confirmation from a herbarium record in Forest Research Institute, collected by Dr. Brandis in 1880 (Bennet *et al.* 1978) and further confirmed by the author in 2008. This past record has been well elaborated by Sushilkumar (2005). From these records, it is clear that *P. hysterophrus* has entered in India before the start of 20^{th} century and survived unknown till 1955. But, it is also true that after 1955, *Parthenium* has spread like a wild fire throughout India. The rapid spread of *Parthenium* after 1955 in India was possible due to large-scale import of wheat and other cereals under PL480 grants of USA during fifties of 20^{th} century.

Parthenium spread rapidly throughout the country through Public Distribution System (PDS) and become noticeable. This is the reason that in most of publication, *Parthenium* occurrence is considered after 1955 in spite of its record much earlier.

Now, *Parthenium* occurs throughout country in about 35 million hectares of land (Sushilkumar and Varshney 2010). After being established in India, *Parthenium* has gradually spread into most of its neighboring countries like Pakistan (Shabbir and Bajwa 2006), Sri Lanka (Jayasurya 2005), Bangladesh (Rahman *et al*. 2008, Karim 2009) and Nepal (Mishra 1991, Adhikari and Tiwari 2004, Shrestha *et al.* 2014).

The spread of *Parthenium* has been reported from all states of India in varying intensity. The spread and invasion of *Parthenium* may be severe in some of the areas of a particular state and may be low to nil in other areas. In Uttarakhand and Himachal Pradesh, it is abundantly occurred in lower altitude, but density and occurrence gradually declined towards higher altitude. For example, in Uttarakhand state of India, Parthenium density is higher in lower elevations at Roorkee, Rishikesh, Haridwar *etc* but its density and occurrence gradually declines towards higher elevations like Devprayag, Srinagar, Parui and become nil at Joshimath. In Maharashtra, its occurrence is negligible in Konkan region while in other areas, it is abundantly occurred.

The overall average infestation of *Parthenium* varied in different states of India (Table 1). In general, overall spread in terms of density and infestation level was highest in Andhra Pradesh, Bihar, Chhattisgarh, Delhi, Haryana, Karnataka, Maharashtra, Madhya Pradesh, Punjab, Tamil Nadu and Uttar Pradesh; medium in Assam, Gujrat, Himachal Pradesh, Jharkhand, Jammu & Kashmir, Uttarakhand, Odisha, West Bengal and Rajasthan; low in Andaman & Nicobar, Arunachal Pradesh, Goa Kerala, Lakshadweep, Manipur, Mizoram, Mehgalaya, Nagaland, Pondicherry and Sikkim (Sushilkumar 2012). It is experienced that *P. hysterophorus* infestation is increasing rapidly in India and may be more widespread than shown here. In a survey report, Abraham and Girija (2005) has shown high density of *Parthenium* in Kerala state of India, but in general *Parthenium* is not a major weed in this state and it is restricted to only district Palakkad adjoining to border of Tamil Nadu state, where the weed is in abundance. In 2012, severe infestation of *Parthenium* was reported in the Mincoy island of Lakshadweep in India. Systematic surveys of *Parthenium* infested areas on 12 selected national highways of North-Eastern India were conducted during 2009-2011 by by Devi *et al*. (2013). Survey revealed the presence of *P. hysterophorus* in all the sites but severe infestation was recorded in NH-31 (Bongaigoan), high in NH-37 (Nagoan) and NH-39 (Imphal), medium in NH-37 (Jorhat), NH-44 (Agartala,Tripura), NH-52 (Tezpur) and NH-53 (Imphal-Jiri), mild in NH-39 Nagland), NH-40 (Shillong, Meghalaya), NH-54 (Aizawl, Mizoram) and NH-150 (Imphal) while negligible infestation was observed in NH-52A (Itanagar, Arunachal Pradesh) during the month of June to August.

In a detail study, Sushilkumar and Varshney (2010) revealed that *Parthenium* spread and infestation till 1960 was restricted to Maharashtra and border areas of adjoining states. Subsequently by 1970, *Parthenium* infestation increased inside of all the nearby states of Maharashtra. From 1970 onward, it rapidly spread throughout the country except a few states. The information collected from Krishi Vigyan

Table 1. Spread and infestation level of *Parthenium* in India

Name of state	Over all spread and infestation level of *Parthenium*	Name of state	Over all spread and infestation level of *Partheniu*
Andaman & Nicobar islands	Low	Kerala	Low
Andhra Pradesh	High	Madhya Pradesh	High
Arunachal Pradesh	Low	Maharashtra	High
Assam	Medium	Manipur	Low
Bihar	High	Meghalaya	Low
Chattishgarh	Medium	Mizoram	Low
Chandigarh	Medium	Nagaland	Low
Delhi	High	Orissa	Medium
Goa	Low	Pondicherry	Medium
Gujarat	Low	Punjab	High
Haryana	High	Rajasthan	Medium
Himachal Pradesh	Medium	Sikkim	Low
Jammu & Kashmir	Medium	Tamil Nadu	High
Jharkhand	Medium	Uttar Pradesh	High
Karnataka	High	Uttarakhand	Medium

Source: Sushilkumar (2012)

Table 2. Estimated infested area by *Parthenium* in India during different decades since 1955

Period	Infestation (in million ha) in different land like barren, fallow, wasteland, including land under non-agricultural uses	Crop land	Forest land	Total infested area (mha)
1955-1960	0.5	0	0	0.5
1961-1970	1.75	0.25	0	2.0
1971-1980	4.5	0.5	0	5.0
1981-1990	6.0	1.0	0	7.0
1991-2000	7.5	2.0	0.5	10.0
2001-2009	18.78	14.25	2.0	35.0

Source: Sushilkumar and Varshney (2010)

Kendra (KVKs) [Agricultural Science Centre] from all over the country has confirmed the increasing problem of *Parthenium* in almost all parts of the Country. The record of this weed in Kargil region of Jammu & Kashmir, Port Blair in Andaman & Nicobar islands and Minicoy island of Lakshadweep is a pointer to extraordinary ability of the weed to invade new environment. The problem of *Parthenium* in India is particularly serious in rain-fed ecosystem and in non-cropped situations.

Increase in land area infestation with *Parthenium* in India from 1955 to 2009: Sushilkumar and Varshney (2010) studied the spread and infestation of *Parthenium* problem since its first occurrence in India in 1955 in Pune. They found that in beginning, *Parthenium* was only a problem in wasteland and vacant land, but not in the crop areas. Reports stared to appear about its infestation in field crops after 1980. Likewise, reports of *Parthenium* infestation in forest area also started to appear after 1990. On the basis of published information of *Parthenium* infestation in wasteland, crop land and forest area, they estimated about 35 million hectares of land infested with *Parthenium* in India. The increase of *Parthenium* infestation in crop area in recent past was alarming (Table 2).

Menace of *Parthenium* in crop, orchards, pasture and forest ecosystems and human and animal health

The harmful effects of *Parthenium* have been reported world over in different ecosystems with different intensity. In the beginning of its infestation in India, *Parthenium* was known as a weed of wasteland as it used to seldom occur in crops but now it has spread in almost all types of cereal, pulse and vegetable crops besides pasture and forest ecosystems. In agricultural fields, where only one crop is taken in a year, it grows profusely in fallow period with the occurrence of mild rains. It has become a serious problem on grass availability in pastures land. In many forests, National Parks and Reserved forests, the weed has achieved the alarming status and has become a major concern for the survival of carnivores, which survives on herbivores that are mainly dependant on grasses. In India, this weed has been considered as one of the greatest sources of dermatitis, asthma, nasal-dermal and naso-bronchial types of diseases. In general, *Parthenium* is a poisonous, pernicious, problematic, allergic and aggressive weed posing a serious threat to human beings and their livestock.

Impact of *Parthenium* on agriculture and pastures ecosystems*:* *Parthenium* has gradually entered into field crops, causing considerable yield losses. In different states of India like Andhra Pradesh, Bihar, Haryana Karnataka, Madhya Pradesh, Tamil Nadu and Uttar Pradesh, it has been considered a serious weed of crop lands. Sushilkumar and Varshney (2010) estimated infestation of *Parthenium* in 18.78 and 14.25 million hectare land in barren, fallow, wasteland including land under non-agricultural uses and crop lands, respectively. Studies showing losses by *Parthenium* in field crops are limited. Das (2008) observed severe *Parthenium* competition between 15 and 45 days after sowing while Tamado *et al*. (2002) between 5 and 59 days after emergence in sorghum. Grain yield reductions due to infestation of *Parthenium* up to 40% in agricultural crops, like rice, wheat, maize, pigeonpea, blackgram, sorghum *etc* are known (Khosla and Sobti 1979, 1981, Shabbir and Bajwa 2006).

Parsons and Cuthbertson (1992) reported that *Parthenium* caused a substantial yield loss in sunflower and sorghum in central Queensland, Australia. Similarly, up to 90% reduction in forage production in grasslands has been reported from India (Vertak 1968, Nath 1988). According to Parades and Labrada (1986), one *Parthenium* plant per m^2 was the critical threshold density in direct-seeded tomato whereas a *Parthenium* density of 6 plants per m^2 was reported to be critical threshold in transplanted tomato (Morales-Payan 2000) as it resulted in 63% reduction in its plant biomass and yield. Angiras and Saini (1997) reported sorghum grain and forage yield losses of 40 and 90%, respectively by *Parthenium*. Sorghum grain yield was reported to be declined by 40-95%, if *Parthenium* is left uncontrolled throughout the growing season (Tamado *et al*. 2002). Kumari *et al.* (2014) studied the impact of *Parthenium* invasion on species diversity of cultivated filed in Bilaspur (Chhattisgarh, India).

Parthenium affects crop growth through allelopathy. Initially, Jayachandra (1971) Kanchan and Jayachandra (1975) reported the presence of plant growth inhibitors in *Parthenium*. Many workers have evidently shown the effect of aqueous extracts of leaf, inflorescence, stem, and root of *Parthenium* to reduce germination of crops seeds and to reduce root/shoot length, root/shoot dry weights *etc*.(Knox *et al.* 2011). Maharjan *et al*. (2007) showed that increase in concentration of extract was invariably associated with decrease in germination and seedling characteristics of the crops. A strong inhibitory effect of aqueous extract of *Parthenium* on the root elongation of cereal seedlings was reported (Khan *et al.* 2011).

Gupta and Narayan (2010) found that species varied considerably in their sensitivity to the aqueous extracts of *Parthenium* for germination and growth and allelopathic impact of *Parthenium* depends on the quality of leaf biomass. *Parthenium* residues in soil affected the emergence and growth of plant species by releasing phenolics rather than decreasing the available nutrient status in the soil (Singh *et al*. 2005). In an aquatic environment, Pandey (1996) found gradual loosing of phyto-toxicity effect of *Parthenium* in control of aquatic weeds in about 30 days. Ambiye and Golatkar (2010) reported tannins, saponins, cardiac glycosides, and steroids in leaves and shoots of *Parthenium*. The inhibitory role of allelochemicals, particularly parthenin, was dependable on the amount of plant material accumulated on the soil surface and the concentration of parthenin in residues (Belz 2008).

Impact of *Parthenium* on orchards and forests ecosystem: Earlier, it was not considered a weed of orchards and forests but now it has spread rapidly in these areas too. *Parthenium* grows luxuriantly in orchards due to less frequent weeding in such ecosystems. In Himachal Pradesh, *Parthenium* has invaded majority of apple orchards in lower elevations (Bisht 2004).The invasion of *Parthenium* was reported in forest and wastelands with little or no growth of any other species and local bio-diversity was found to be threatened (Kumar and Rohatgi 1999). In many forests, National Parks and Reserved forests, the occurrence of this weed has been noticed world over. Pandey and Saini (2002) observed *Parthenium* invasion near the people habitation, crop lands, grazing lands in between the forest ecosystem in remote areas of natural forest in Madhya Pradesh. *Parthenium* has been observed in many forest nurseries in Madhya Pradesh. It had became a nuisance during 2000 in RajaJi National Parks in Uttarakhand (Goyal and Brahma 2001). The weed was observed in India at alarming rates by the author during 2010 and 2011 in Pench National Park. Author observed the weed in plenty in buffer zone of Kanha National Park and in low profile in core area too. The *Parthenium* has become a problem in Van Vihar National Park in Bhopal (Madhya Pradesh, India), where large area of grasses was replaced by the weed. This situation compelled the authorities of National Park to uproot the weed by deputing large number of labours to restore the grasses. *Parthenium* has been found responsible to reduce grass availability to herbivores in Corbett National Park in Uttarakhand (India). Sushilkumar and Varshney (2010) estimated the invasion of *Parthenium* in about 2 million hectare land of forest in India. Kumar *et al.* (2013) studied the distribution and effect of plant species density including *Parthenium* in sub-watershed of Rajouri Forest Range of Jammu & Kashmir (India). Among the eight species recorded in the area, *Parthenium* showed maximum density and importance value index which posed a significant threat to economic development and ecological integrity. *Parthenium* rapidly invaded new surroundings and replaced the indigenous species and posed a serious threat to biodiversity, reducing pasture productivity and hence fodder supply. Sushilkumar (2013) has reviewed the menace of *Parthenium* in different protected areas of India and suggested the National Parks' authorities to allow systematic rlease of bioagent *Z. bicolorata* in the protected aeas which is banned as per the rules and regulations of National Parks. In India, deliberate introduction of any exotic species in National Parks is banned in spite of the fact that good control of *Parthenium* by the *Z. bicolorta* was reported in Rajajee National Park (Goyal and Brahma 2001) and Pench National Park (personal observations). The weed has invaded the buffer zone of Chitwan National Park in Nepal, a World Natural Heritage site (Shrestha 2012). The weed has become a major threat in Kruger National Park in South Africa (Strathie *et al*. 2011) and the Masai Mara/Serengeti ecosystem in Kenya and Tanzania, which is home to an estimated 2 million wildebeest which depend upon this ecosystem for their survival (IUCN 2011). In Australia, the weed is present in Carnarvon National Park (Adkins and Shabbir 2014).

Parthenium menace on human and animal health: In India and Australia, this weed has been considered as one of the greatest source of dermatitis, asthma, nasal-dermal and naso-bronchial types of diseases. In general, *Parthenium* is a serious threat to human beings and their livestock. A major population does not feel any sensitization when they come in contact with *Parthenium* first time or for some time. But, chances of getting sensitized to the weed are high, when a person comes in contact for a period ranging from 4-15 months. *Parthenium* was detected to be the main cause of dermatitis in hundreds of cases in India in Pune (Maharashtra), Patna (Bihar) and Coimbatore (Tamil Nadu) by Ranade (1976), Chandra (1973) and Rajulu and Gowri 1976), respectively. Fisher (1996) described the incidence and severity of contact dermatitis in humans caused by *Parthenium* in India. It was argued to be the first reported instance of an imported sensitizer causing allergic dermatitis in thousands of people. Kologi *et al.* (1997) also reported the dermatological hazards in human beings. *Parthenium* was found to be predominant in the city's atmosphere (Agashe and Alfadil 1989) after its invasion in 1965 in Bangalore (Jayachandra 1971) and an increase in the incidence of naso-bronchial allergies was reported coincided with the steady and widespread growth of the weed. Random clinical surveys showed that 7.1 per cent of the study population in this area was suffering from allergic rhinitis resulting from exposure to *Parthenium* pollen (Sriramarao *et al.* 1991). Rs 800 crores were estimated to be spent for the treatment of *Parthenium* related diseses in human beings in india (Sushilkumar and Varshney 2010).

McFadyen (1995) has reviewed the information on health aspects in Australia caused by pollens and *Parthenium* dust in Central Queensland. The cost of treating symptoms can be more than $40 per month for severely affected people i Australia (Commonwealth of Australia 2012). Allergic responses can be significant with negative impacts on home, work and social aspects of living. There is a paucity of diagnostic and health care provision for individuals with allergic responses to the weed. Farmers, particularly those involved in manual fodder harvesting, developed eye inflammation and skin dermatitis on the exposed parts of their hands in Nepal (Karki 2009). Kumar (2014) has reviewed and discussed the impact of *Parthenium* on living world.

Parthenium is not palatable to livestock due to its irritating odour, taste and presence of trichomes, but, sometimes-hungry cattle may eat *Parthenium* during summer season when other green vegetations are scanty. In such cases, the weed was found to cause clinical signs such as salivation, onset of diarrhea, anorexia, pruritus, alopecia and dermatitis. In cattle, due to *Parthenium* contact, there may be loss of hair and marked depigmentation of skin. The bitter and reduced milk yield contaminated with parthenin has been reported in buffaloes and goats, fed on grass mixed with *Parthenium*. In Queensland (Australia), losses to the cattle industry due to *Parthenium* have been estimated to be $ 16.5 million per year in term of control costs and loss of pasture (Chippendale and Panetta 1994). The weed is poisonous to livestock and may cause death after 30 days if significant quantities are ingested (Ahamed *et al.* 1988). Chemicals within the plant are thought to alter the microbial composition of the rumen of dairy cattle, buffalo and sheep and can impart a bitter taste to their milk and the meat of cattle and sheep can develop an undesirable flavor (Tudor *et al.* 1982, Sushilkumar 2005, 2012).

Parthenium management

Ever since the weed became a menace, efforts are being made to manage the weed by different methods world over. So far, no single method has been proved satisfactorily as each method suffers from one or more limitations such as impracticability, temporary relief, environmental safety, high cost *etc.* A brief of different methods in practice is being given below in context to their applicability and practicability in different type of situations and ecosystems.

Mechanical and manual management: This method is applicable in all type of ecosystems in limited area in spite of high cost involved. The relief from this method is temporary and needs to be repeated on reappearing of the weed. Mechanical removal with the help of tractor, plough, *etc.* is possible up to certain extent and that too only in open fields without crop or if crops are sown in lines. Cuttings of *Parthenium* with the sword enhance its regeneration. After cuttings, large numbers of shoots are sprouted from the cut stems and flowers are produced on such shoots early than the normal plant. Therefore, cutting should be avoided under physical management. If mechanical or manual methods are to be adopted, *Parthenium* should be uprooted and such operations should be completed before flowering. Uprooting is practicable only during rainy season when soil becomes wet and plants are easily uprooted with tap roots, which is not possible during summer or winter season. Uprooting should be done by using hand globs of leather, cloths or plastic to avoid direct close contact with the skin. Uprooting of *Parthenium* by farmers is practicable only in high valued crop or in small area due to high labour cost.

It was estimated that, Rs. 182000 million or 18200 crores were required in the year 2009 to manage the weed by manual methods in 35 million hectare of land in India (Sushilkumar and Varshney 2010). However, if uprooting is done on community basis, large area may be cleaned. In India, large number of students, farmers and general public were motivated to participate in uprooting of *Parthenium* from their colony, schools, campus and public places during '*Parthenium* Awareness Week' organized by Directorate of Weed Research (DWR), Jabalpur every year during 2005 to 2013. These events were documented in the form of reports by Gogoi *et al.* (2005), Varshney and Sushilkumar (2006, 2007, 2008, 2009, 2010), Sushilkumar and Ranganatha (2011) and Sushilkumar and Sharma (2012). Use of fire was tried in Australia to manage the weeds, but it did not prove practicable due to fast germination of *Parthenium* from the available seed bank in the soil in the niche vacated by the fire in the absence of vegetation (Vogler *et al*. 2000).

Cultural management: This method may be applicable in crop ecosystem. It has been observed that in some crop fields, *Parthenium* grows profusely. To reduce the seed bank in such crops, some fast growing species of fodders like barseem and sorghum can be taken to suppress *Parthenium* and its seed bank in the field (Sushilkumar 205, 2012). Reductions in the stock in rate and more appropriate rotational timings between grazing events are other useful methods for managing *Parthenium* weed in pastures (Adkins and Shabbir 2014).

Preventive management through legislative measures: The proverb 'prevention is better than cure' is applicable in all the countries affected with *Parthenium*. It may be implemented by enforcing suitable legislative tools and following up action by the government. In Australia, machinery and vehicles coming from infested areas and entering into non-infested area must be cleaned thoroughly to remove *Parthenium* seeds. This is done by washing with a high-pressure hose or by using roadside washdown facilities (Parsons and Cuthbertson 1992). In other countries including India, such strict measures are seldom followed. In Australia, *Parthenium* is a declared weed in all states and territories, and, landowners are directed to control it and/or report it to the concerned state authorities immediately after spotting it (Adkins and Shabbir 2014).

So far, very few legislative measures have been enforced for *Parthenium* in other countries. The management of *Parthenium* was also tried in India through the legal act, first in Karnataka State in 1975 , declaring *Parthenium* a noxious weed under 'The Karnataka Agricultural Pests And Diseases Act, 1969. Under this act, notices were issued to public in Bengaluru during the eighties by Municipal Corporation to remove *Parthenium*, but there did not appear any follow up action. Thus, in spite of this comprehensive act, it was total failure to get the weed removed from Bengaluru. Similarly, in Sri Lanka, *Parthenium* was also declared a noxious weed and under this legislation, the movement of adult plants to areas that are not presently infested is strictly forbidden (Dhileepan 2009)

Chemical management: The management of *Parthenium* by herbicides was considered only a viable option by Balyan *et al.* (1997) but the effect of herbicide was considered of temporary nature and repeated operations were required. Chemical treatment can only kill existing population at the given sites but can not prevent the entry of the seeds coming on treated side from neighboring places. (Sushilkumar 2005, Sushilkumar 2012). Nevertheless, in limited situations, chemical use is financially feasible like in high-value crops and in the situations like along roadsides, in public parks *etc*. Chemical control of *Parthenium* over a vast area like wastelands, rangelands, community land or within forests where the weed commonly found is not cost effective. Sushilkumar and Varshney (2010) estimated the requirement of Rs. 126000 million or Rs. 12600 crores to control 35 million hectares of *Parthenium* infested land in India for one time spray of chemical.

The chemical approach may be applied in wasteland, crop land, and orchards type of ecosystems depending on the situations and area infested. It is easy to use herbicides in wasteland situation where there is no danger of crop damage but in crop ecosystem, expert knowledge is required to apply suitable herbicide depending on the crop in the field (Sushilkumar 2012). A large number of herbicides have been tested against *Parthenium* in cropped and non-cropped situations (Mishra and Bhan, 1996, Brar and Walia, 1991, Sushilkumar 2012). In wasteland situation, if grasses are to be saved and *Parthenium* is to be killed, metribuzin (0.3 to 0.5%) should be used. 2,4-D (1 to 1.5 kg/ha) and metribuzin (0.3 to 0.5%) can safely be used in crops of grass family like sorghum, sugarcane, wheat, rice, oat *etc* (Brar and Walia 1991). For complete vegetation management including *Parthenium*, glyphosate (1 to 1.5 kg/ha) is recommended. Diquat 0.5 kg/ha in 500 litre spray effectively controlled *Parthenium* at all growth stages (Dhanraj and Mitra 1976). Mishra and Bhan (1994) tested six herbicides against *Parthenium* and associated weeds in soybean. Bentazon 1.5 kg/ha applied at 25 days after sowing effectively controlled *Parthenium*, *Commelina benghalensis* and yellow nut sedge (*Cyperus iria*) in soybean. Metribuzin (0.50 to 0.75 kg/ha) may be used as pre-emergence herbicide for control *Parthenium* in potato, tomato and soybean just after sowing. Atrazin (1-1.5 kg/ha) may be used in maize as pre-emergence herbicides. Diauron yr (1-1.5 kg/ha) may be used in maize as pre-emergence herbicides. Chloromuron-methyl (10-12 g/ha) may be used to kill *Parthenium* in soybean after 25-3- days of sowing.

Biological management: Biological control has been considered most effective method against *Parthenium* in waste land, pasture, orchards and forest ecosystems by introduction of bioagent from the native place of the weeds under classical biological approache. During last two decades, much emphasis has been given to control *Parthenium* through various biological agents like pathogens, insects and plants.

(i) Biological management of Parthenium through pathogens: In India, there are many records of various pathogenic and non-pathogenic microorganisms on *Parthenium*. In spite of the presence of many pathogens, not all have been evaluated as biological control agents against the weed (Aneja *et al.* 1994, Kauraw *et al.* 1997, Pandey *et al.* 2005). Sushilkumar (2009) reviewed the status of biological control of *Parthenium* by insects and pathogens in India. In Australia, two rust species, *Puccinia abrupt* var. *partheniicola* (Jackson) Parmelee (winter rust) and *Puccinia xanthii* var. *Parthenium hysterophorae* (summer rust) have established in the field, but their prevalence and impact is highly variable and sporadic, depending upon the local climatic conditions (Dhileepan *et al.* 1996). Efforts to establish these fungi in India were advocated (Evans 1997) but so far no success have been achieved.

(ii) Biological management of Parthenium through insects: (a) By indigenous insects- In India, many insects have been reported on *Parthenium* but none of indigenous insect was found host specific yet (Sushilkumar 2009). Nevertheless, some time, indigenous insects may also play important role. A cerembycid *Nupserha* sp. was found to cause widespread damage (5-95%) to *Parthenium* (Sushilkumar 2012).

(b) By exotic insects: Classical biological control is one of the most important methods used for the management of invasive weeds. In this method, insect herbivores or plant pathogens from the native range of the weed are introduced, to suppress the growth of the weed, in the introduced range. So far, only four countries (Australia, South Africa, India, Tanzania and Sri Lanka) have released biological control agents against *Parthenium*. A further two countries (Ethiopia and Vanuatu) are in the process of releasing biological control agents, and others (Kenya, Pakistan, Nepal, China, Ethiopia) have agents that have accidentally arrived there (Adkins and Shabbir 2014).

In India in 1983 at Bengaluru, three insects namely defoliating beetle *Zygogramma bicolorata* Pallister (Coleoptera: Chrysomelidae), the flower feeding weevil *Smicronyx lutulentus* Dietz (Coleoptera: Curculionidiae) and the stem boring moth *Epiblema strenuana* (Walker) (Lepidoptera:Tortricidae) were imported in India (Singh 1989,1993). *S. lutulentus* could not be multiplied in the laboratory while *E. strenuana* was found to complete its life cycle on a oil seed crop niger (*Guizotia abyssinica*L.(Asteraceae) hence, its culture was destroyed (Jayanth 1987) in spite of the fact that this insect was considered to be a potential biocontrol agent in Australia (McFadyen 1985, Dhileepan 2009). After host specificity test *Z. bicolorata* was released which spread over 200 000 sq km area by 1994 (Jayanth and Visalakshy 1994). Soon after release, *Z. bicolorata* involved in controversy about its host specificity due to its occasional feeding on sunflower (Sridhar 1991, Sushilkumar and Bhan 1996), but after indepth studies under the supervision of Fact Finding Committee constituted by Government of India, the insect was declared safe and ban was lifted for its release (Sushilkumar 2009).

After first release of *Z. bicolorata* in Bengaluru in 1984 in India (Jayanth 1987) and due to deliberate introductions to different regions of the country by Directorate of Weed Research (DWR), Jabalpur after lifting of ban on release of the bioagent, it has widely spread across the country (Sushilkumar 2005, 2009 and 20012; Sushilkumar and Varsheny 2007). Incidence of *Z. bicolorata* has been recorded mild to heavy in most of the states wherever it was introduced. An economic benefit of 12150% was recorded by 6^{th} years of its initial release comparing single application of herbicides (Sushilkumar 2006).

In India, establishment of *Z. bicolorata* has been reported corresponding to the level of infestation. This could be possible because of increased biological control efforts by DWR since 2001 by sending the beetles by post to almost all the Krishi Vigyan Kendras (KVKs) and All India Coordinated Research Project on Weed control. Sushilkumar (2005) after observing the widespread establishment of *Z. bicolorata* in Ludhiana up to Bagha border (Punjab) forecasted the bioagent entry from this route to Pakistan. Later on, Javaid and Shabbir (2006) spotted this bioagent first time from Lahor and Changa Manga Forest area of Pakistan. In Nepal too, the bioagent was entered from the nearby released places of Uttar Pradesh. This widespread occurrence of *Z. bicolorata* in India is in contrast to earlier predictions (Jayanth and Bali 1993), who suggested that *Z. bicolorata* would not be suitable for hot regions of Central and West India and cold regions of Himachal Pradesh, Uttarakhand, Punjab and Western Uttar Pradesh. Dhileepan and Senaratne (2009) have also found the occurrence of *Z. bicolorata* in very hot and cold regions of India. Diapause in *Z. bicolorata* has been considered a negative attribute which hampers its activity (Jayanth and Bali 1993a). The diapause was broken by regulation of temperature to enhance the activity of *Z. bicolorta.* After breaking of diapause, femail laid eggs normally (Sushilkumar and Ray 2010). In crop situations, *Z. bicolorata* was found to have limited scope due to disturbance of soil during agricultural activities. However, biological control approach may be viable through augmentation of the bioagent as was demonstrated by (Sushilkumar and Ray 2011). The augmentation of bioagent may be achieved through large scale multiplication in net houses (Sushilkumar 2005).

In India, *Z. bicolorata* has well established in Andhra Pradesh, Bihar, Delhi, Haryana, Karnataka, Maharashtra, Madhya Pradesh, Punjab, Uttar Pradesh and lower hills of Himachal Pradesh and Uttarakhand, while it has medium spread and established in Odisha, Rajasthan, Tamil Nadu, upper hills of Uttarakhand and Himachal Pradesh and low established and spread in Assam, Jharkhand, Gujrat, Kerala and West Bengal. It has nil to negligible spread in Andman & Nicobar, Arunachal Pradesh, Goa, Meghalaya, Mizoram, Manipur, Sikkim, *etc* .In Tamil Nadu and Andhra Pradesh, *Z. bicolorata* has been well spread only in Western and Northern and North and West regions, respectively. In general, the incidence and spread of *Z. bicolorata* was recorded negligible in all the coastal regions besides cold and hot deserts of India (Sushilkumar 2005, 2012).

Classical biological control work in Australia is the most widely used methods and so far, 11 biological control agents (nine insect species and two rust fungi) have been released into the field. Several of these released agents have established in the field, but only three bioagents namely *Epiblema strenuana* (a stem-galling moth), *Zygogramma bicolorata* r (a leaf-feeding beetle) and *Listronotus setosipennis* (a stem boring weevil) appeared to be have a significant impact upon weed in the field Dhileepan (2009), Dhileepan and McFadyen (2012)

(iii) ***Biological management of Parthenium by competitive replacement through plants:*** This approach has also gained momentum after reports from India that *Cassia sericea* (=*C. uniflora*) can be used to control *Parthenium* in India (Singh 1983). *Cassia sericea*, a non-nitrogen fixing leguminous plant was suggested to be used by adopting two approaches *viz*. maintaining of naturally occurring bio-diversity and planting of species in target area (Mahadevappa 2009). In a nation wide survey under coordinated project sponsored by Department of Biotechnology (DBT), India, plant species namely *Xanthium strumarium, Tephrosia purpurea, Achyranthes aspera,Vitex negundo, Cassia sericea, Cassia tora, Cassia* spp. and *Cannabis sativa* were found to be competitive against the weed. *X. strumarium, T. purpurea, Cassia sericea* and *Cassia tora* were found most abundant species in wasteland, community land and along the road and railway track sides. After indepth deliberation of different attributes of these botanicals, *Cassia tora* was recommended to replace *Parthenium* (Yaduraju *et al.* 2005, Sushilkumar 2012).

In Jabalpur (Madhya Pradesh, India), replacement of *Parthenium* by marigold showed encouraging results and this practice was also advocated for *Parthenium* suppression (Sushilkumar 2011) in protected premises to suppress the weed apart of enhancing aesthetic value. In and around Jabalpur and many other districts of Madhya Pradesh *Cassia tora* was found to replace *Parthenium* naturally (Sushilkumar and Bhan 1997). In Jabalpur, replacement of *Parthenium* by *Cassia tora* has been well demonstrated along the road side by Sushilkumar (2011).

In Australia, Bowen *et al.* (2007) tested a number of grass and legume species against the *Parthenium* plants. Khan *et al.* (2013) tested a number of native and introduced pasture species and found that several of them suppressed *Parthenium* growth in both glasshouse and field conditions. The study of Navie *et al.* (1998) showed that the combined action of the stem-galling moth (*Epiblema strenuana*) and buffel grass (*Cenchrus cilla*ris) could significantly compromise the vegetative and reproductive growth of the weed. More recently, Shabbir *et al.* (2013) showed in a field study that biological control agents and suppressive plants can act together significantly to reduce the biomass and seed production of *Parthenium*.

Parthenium* management through its utilization*: The large scale utilization of *Parthenium* may also be one of the effective methods to manage the weed. Keeping in view the huge green and dry biomass of *Parthenium*, available in India and other countries, there is need to change this curse to boon by harnessing its various uses. The potential use of *Parthenium* was reviewed by Ramaswami (1997) and Varsheny and Sushilkumar 2010).

(i)Parthenium use as biopesticde: *Parthenium* has been well documented for its insecticidal, nematicidal and herbicidal properties (Gajendra and Gopalan 1982) besides oxalic acid (Mane *et al.* 1986) and biogas production (Gunasheelan 1987). Datta and Saxena (1996) have shown antifeedant efficacy of parthenin and it's dehydrated product to a polyphagous insect *Spodoptera litura*. Singh and Sushilkumar (2004) have found its antifeedant activity against forest pests. It was very interesting finding that *Parthenium* does not act only as an antifeedant or inhibitor but for silkworm, it also act as a phagostimulant (Patil *et al.* 1997). Pandey (1996) found sesquiterpene lactone parthenin, one of the major toxins in *Parthenium* toxic at 50 PPM to the floating aquatic weeds pistia (*Pistia stratiotes*) and lemna (*Lemna pausicostata*), and at 100 PPM to water hyacinth (*Eichhornia crassipes*), salvinia (*Salvinia molesta*), azolla (*Azolla nilotica*) and spirodella *Spirodela polyrhiza*. The lethal dose for the submerged weeds najas (*Najas graminea*), ceratophyllum (*Ceratophyllum demersum*) and hydrilla (*Hydrilla verticillata*) was 25 ppm.

(ii) Parthenium use as compost and vermi-compost: Compost and vermi-compost making from *Parthenium* may be one of the most economical and practical methods for farmers, colony residents, village Panchayat [authority] and municipalities. To ensure the killing of *Parthenium* seeds during compost making, a pit method was standardized and developed at Directorate of Weed Research (DWR) at Jabalpur (Madhya Pradesh). Study showed that compost prepared by mixing *Parthenium* with dung slurry, soil and urea in layers in at least 90 cm deep pit in anaerobic conditions could kill the *Parthenium* seeds also and compost quality was superior than the FYM (Sushilkumar *et al.* 2005). Likewise, *Parthenium* green biomass can also be converted into vermi-compost which has more nutrients than the compost prepared from pit method. *Parthenium* can also be used as green manure.

***Parthenium* management through stakeholders' participation:** Stakeholders participation recommonded by Sushilkumar and Saraswat (2001), Batish *et al.* (2004) and Sushilkumar (2005) were implimented through nation wide awareness programme and involvment for the management of *Parthenium.* It may be cited as an example to motivate people of other countries suffering from the menace of *Parthenium*. Directorate of Weed Research, Jabalpur initiated and organized people awareness raising activities throughout India involving different stakeholders like 24 centres of All India Co-ordinating Programme on Weed Control (AICRP-WC) representing almost every state of India , about 550 KVKs located in various disticts of each state, about 100 institutes under Indian Council of Agricultural Research (ICAR), many NGOs, environmental agencies, students and farmers. For effective participation of stakeholders, posters, books, extension folders and video films on *Parthenium* management were developed and distributed to them with the request to organize awareness activities by different ways as deem fit to them. DWR has also organized many training courses on *Parthenium* management for KVKs personnel, NGOs and progressive farmers besides organizing many farmer meetings at village and student meetings at school and college level. Responses received from different stakeholders from all over India proved that large number of people participated in the awareness programme through rallies, practical demonstrations, photo exhibition, film showing and broadcasting programme on radio (Gogoi *et al.* 2005,Varshney and Sushilkumar 2006-2010, Sushilkumar and Ranganatha 2011, Sushilkumar and Sharma 2012).

Integrated *Parthenium* management: From the review of literature and discussion thereon, it is clear that *Parthenium* can not be controlled by adopting any single method. Sushilkumar and Saraswat (1997) strongly advocated that *Parthenium* can be managed effectively only by adopting integrated approaches involving people participation. They suggested Integrated *Parthenium* Management (IMP) scheme involving the integration of all the available methods at different time of the year keeping in view the biology and germination of *Parthenium*. For example, manual removal involving public participation during rainy season when soil is wet and uprooting is easy, use of chemicals during winter and summer as spot treatment, use of botanical like *Cassia tora* and exotic insect *Z. bicolorata* during rainy season and involving *Parthenium* Active Group (PAG).

For effective implementation of *Parthenium* management programme, it was advocated to continue the efforts for at least 5-6 years to exhaust the avail able seed bank in the soil. Further adequate quarantine measures should be adopted to check the immigration and emigration of the weed. Therefore, combined efforts by researchers, social workers, department of horticulture, agriculture and forestry are required (Sushilkumar 2005, Sushilkumar and Varshney 2007). Effective linkage of different regional groups of different countries with international *Parthenium* weed network of Australia was advocated by Adkins and Shabbir (2014) for exchange of information amidst the different countries as in this group 300 members across the 30 countries are involved.

REFERENCES

Abraham CT and Girija T. 2005. Status of *Parthenium* in Kerala, pp. 48-51. In: *Proceedings of Second International Conference on Parthenium Management* held at GKVK, Bangalore (Karnataka),5-7 December 2005.

Adamson DC. 1996. *Introducing dynamic considerations when economically evaluating weeds*. MSc Thesis, The University of Queensland,Brisbane, Australia.

Adhikari B and Tiwari S. 2004. *Parthenium hysterophorus* L.: highly allergic invasive alien plant growing tremendously in Nepal. *Botanica Orientalis* **4**: 36–37.

Adkins SW and Shabbir A. 2014. Biology, ecology and management of the invasive *Parthenium* weed (*Parthenium hysterophorus* L.). *Pest Management Science* **70**: 1023-1029.

Agashe SN, Alfadil AG. 1987. Atmospheric biopollutants monitoring in relation to meterological parameters. *Grana* 28: 97-104.

Ahmed MN, Rao PR and Mahendar M. 1988. Hematological observations in experimental partheniosis in buffalo calves. *Indian Veterinary Journal* **65**: 972-974.

Ambiye N and Golatkar V. 2010. hytochemical analysis of *Lantana camara* and *Parthenium hysterophorus*. *Bioinfolet* **7**(2): 135-136.

Aneja KR, KaurM and Sharma A 1994. Leaf-spot disease of *Parthenium hysterophorus,* a new disease record. *National Academy of Science Letters* **17**: 179-180.

Angiras NN and Saini JP. 1997. Distribution, menace and management of *Parthenium hysterophorus* L. in Himachal Pradesh, pp.13-15. In: *First International Conference on Parthenium Management* held at Dharwad (Karnataka),6-8 October 1997, (Eds. Mahadevappa M and Patil VC), Volume I.

Balyan RS, Yadav A and Malik RK. 1997. Easy and efficient control of carrot weed (*Parthenium hysterophorus* L.), Choudhry Charan Singh Hissar Agricultural University, Extn. Bulletin: 8 p.

Batish DR, Singh HP, Kohli RK, Johar V and Yadav S. 2004. Management of invasive exotic weeds requires community participation. *Weed Technology* **18**: 1445-1448.

Belz RG. 2008. Stimulation versus inhibition-bioactivity of parthenin, a phytochemical from *Parthenium hysterophorus* L. *Dose Response* **6**(1): 80-96.

Bennet SSR, Nathani HP and Raizada MB. 1978. *Parthenium* L. in India - a review and history. *Indian Journal of Forestry* **1**: 128-131.

Bowen D, Ji J and Adkins SW. 2007. Management of *Parthenium* weed through competitive displacement with beneficial plants: a field study. *A report to the Queensland Murray Darling Committee*, The University of Queensland, Brisbane, Australia.

Brar LS and Walia US. 1991. Herbicidal control of congress grass (*Parthenium hysterophorus*). *Indian Journal of Weed Science* **23**: 36-39.

Chandra S. 1973. *Parthenium*-a new dermatitic weed in Bihar, *p.375*. In: *Proceeding of Sixteenth Indian Science Congress*.III.

Chippendale JF and Panetta FD. 1994. The cost of *Parthenium* weed to the Queensland cattle industry. *Plant Protection Quarterly* **9**: 73-76.

Commonwealth of Australia. 2012. Weeds of national significance. *Parthenium* weed (*Parthenium hysterophorus* L.) strategic plan 2012–17: 34 p.

Dale IJ.1981. *Parthenium* weed in the Americas. *Australian Weeds* **1**: 8-14.

Dam DP, Dutta RM and Dam N. 1993. An early collection record of *Parthenium hysterophorus* L. from botanic garden, Calcutta. *Journal of Bombay Natural History Society,* **90**: 128.

Das TK. 2008. *Weed Science: Basics and Applications*, 1st edition. Jain Brothers, New Delhi.

Datta Subhendu and Saxena Dinesh B. 2001. Pesticidal properties of parthenin (from *Parthenium hysterophorus*) and related compounds. *Pest Management Science* **57** (1): 95-1011.

Devi YN, Ghanapyari K, Dutta BK, Ray DC and Singh I. 2013. *Parthenium* infestation and evaluation of botanicals and bioagents for its management. *Indian Journal of Weed Science* **45**(3): 62-67.

Dhanraj RE and Mitra MK. 1976. Control of *Parthenium hysterophorus* L. with Diquat. *Proceedings of the National Academy of Science of the United States of America* **22**: 269-272.

Dhileepan K. 2009. Managing *Parthenium* across diverse landscapes: prospects and limitations, pp. 227-259. In: *Management of Invasive Weeds* (Ed. Inderjit), Springer Science Business Media, Knoxville, USA.

Dhileepan K and Senaratne Wilmot KAD. 2009. How widespread is *Parthenium hysterophorus* and its biological control agent *Zygogramma bicolorata* in South Asia? *Weed Research* **49**: 557-562.

Dhileepan K, Madigan B, Vitelli M, McFadyen R, Webster K and Trevino M. 1996. A new initiative in the biological control of *Parthenium*. *Proceedings of 11th Australian Weeds Conference*, Melbourne, Australia.

Evans HC. 1997. *Partheniumhysterophorus*: a review of its weed status and the possibilities for biological control. *Biocontrol News Information* **18**: 89-98.

Fisher AA. 1996. Esoteric contact dermatitis. Part IV: devastating contact dermatitis in India produced by American *Parthenium* weed (the scourge of India). *Cutis New York,* **57**: 297-298.

Gajendran G and Gopalan M. 1982. Notes on the antifeedant activity of *P. hysterophorus* Linn. on *Spodoptera litura* Fabricious (Lipidoptera: Nocuidae). *Indian Journal of Agriculture Science* **52**: 203-205.

GISD. 2014. *Parthenium hysterophorus*. Global Invasive Species Database. http://www.issg.org/database/welcome/(accessed on 10 February 2014).

Gogoi AK, Mishra JS, Dubey RP. 2005. *A Report of Parthenium Awareness Week*, 34 p.

Goyal CP and Brahma BC. 2001, A ray of hope against *Parthenium* in Rajaji National Park *Indian Forester* **127(**4): 409-414.

Gunaseelan V.N.1987. *Parthenium* as an additive with cattle manure in biogas production. *Biological Wastes,* **21**(3): 195-202.

Gupta and Narayana R. 2010. Effects of applied leaf biomass of *Parthenium hysterophorus*, *Cassia obtusifolia* and *Achyranthes aspera* on seed germination and seedling growth of wheat and pea. *Allelopathy Journal* **26**(1): 59-70

Haseler WH. 1976. *Parthenium hysterophorus* L. in Australia. *Proceedings of the National Academy of Science of the United States of America* **22**: 515-517.

Holm LG, Plucknett DL, Pancho JV, and Herberger JP. 1977. *The World's Worst Weeds*. Universityof Hawaii, 609 p.

Holm L, Doll J, Holm E, Pancho J, Herberger J. 1997. *World Weeds: Natural Histories and Distribution*. John Wiley & Sons, Inc, New York: 1129 p.

IUCN. 2011. Noxious Weed threatens the biggest wildlife migration on the planet. [Online]. IUCN. Available: http://www. iucn.org/news_homepage/events/?6511/ [25 June 2011].

Jain RK, Sharma AK, Kumar A and Sushilkumar. 2008. Pulping and physical strength properties of bodha and carrot grass as raw material for handmade paper making. *Indian Journal of Weed Science* **40**(1&2): 88-91.

Javaid A and Shabbir A. 2006. First report of biological control of *Parthenium hysterophorus* by *Zygogramma bicolorata* in Pakistan. *Pakistan Journal of Phytopathology* **18**: 199-200.

Jayanth KP and Bali G. 1993. Temperature tolerance of *Zygogramma bicolorata* (Coleoptera: Chrysomelidae) introduced for biological control of *Parthenium hysterophorus* (Asteraceae) in India. *Journal of Entomological Reserch*, **17 (1)**: 27-34

Jayanth KP and Ganga Visalakshy PN. 1994. Dispersal of the *Parthenium* beetle *Zygogramma bicolorata* (Chrysomelidae) in India. *Biocontrol Science and Technology* **4**: 363-365.

Jayasurya AHM. *Parthenium* weed - status and management in Sri Lanka, pp. 36-43. In: *Proceedings of 2nd International Conference on-Parthenium Management*, University of Agricultural Sciences, Bangalore, India, 5-7 December,2005.

Joshi S. 1991. Interference effects of *Cassia uniflora* Mill on *Parthenium hysterophorus* L. *Plant and Soil* **92**: 213-218

Jayachandra, J. (1971). Parthenium **weed** in Mysore State and its control. Current Science 40, 568-569.

. Kanchan SD and Jayachandra. 1975. Allelopathic effects of *Parthenium hysterophorus* L. 2. Leaching of inhibitors from aerial vegetative parts. *Plant and Soil* **55**: 61-66.

Karim SMR. 2009. *Parthenium* Weed: A New Introduction to Bangladesh (Abstract), 21st *Bangladesh Science Conference*, 18–20 February 2009. Bangladesh Agricultural Research Institute, Gazipur, Bangladesh.

Karki D. 2009. *Ecological and socio-economic impact of Parthenium hysterophorus L. invasion in two urban cities of South-Central Nepal*. MSc thesis, Central. Department of Botany, Tribhuvan University, Kathmandu, Nepal.

Kaur Manpreet, Aggarwal NK, Kumar Vikas and Dhiman Romika. 2014. Effects and management of *Parthenium hysterophorus*: A weed of global significance. *International Scholarly Research Notices* Volume 2014, Article ID 368647, 12 p. (http://dx.doi.org/10.1155/2014/368647).

Kauraw LP, Chile A and Bhan VM. 1997. Evaluation of *Fusarium pallidoroseum* (Cooke) Sacc. for the biocontrol of *Parthenium hysterophorus* L. pp. 70-74. In: *Proceedings of First International Conference on Parthenium Management*, Dharwad, India.

Khan IA, Khan R Zarin S. 2011. Allelopathic effects of *Parthenium hysterophorus* L. on seed germination and growth of soybean, mung bean and maize. *Herbologia* **12**, 129-136;

Khan N, O'Donnell C, George D and Adkins SW. 2013. Suppressive ability of selected fodder plants on the growth of *Parthenium hysterophorus*. *Weed Research* **53**: 61-68.

Khosla SN and Sobti SN. 1979. *Parthenium*- a national health hazard, its control and utility - a review. *Pesticides* **13**: 121-127.

Khosla SN and Sobti SN. 1981. Effective control of *Parthenium hysterophorus* L., *Pesticides* **15** (4): 18–19.

Kohli RK, Batish DR, Singh HP and Dogra KS. 2006. Status, invasiveness and environmental threats of three tropical American invasive weeds (*Parthenium hysterophorus* L., *Ageratum Conyzoides* L., *Lantana* camaraL.) in India. *Biological Invasions* **8**:1501–1510

Kologi PD, Kologi SD and Kologi NP. 1997. Dermatological hazards of *Parthenium* in human beings, pp.18-19. In*: First International Conference on Parthenium Management* held at Dharwad (Karnataka),6-8 October 1997, (Eds. Mahadevappa M and Patil VC), Volume I.

Knox J, Jaggi D and Paul MS. 2011. Population dynamics of *Parthenium hysterophorus* (Asterceae) and its biological suppression through *Cassia occidentalis* (Caesalpinaceae). *Turkih Journal of Biology* **35:** 111-119.

Kumar Anil. 1914. *Parthenium Hysterophorus* L. and its impact on living world Indian. *Journal of Science Research* **4**(1): 08-14.

Kumar ARV. 1992. Is the Mexican beetle *Zygogramma bicolorata* (Coleoptera: Chrysomelidae) expanding its host range. *Current Science* **63**: 729-730.

Kumar Dalip, Ahmed Junaid and Singh Surat. 2013. Disturibution and Effect of *Parthenium hysterophorus* L. in Mehari Sub-Watershed of Rajouri Forest Range, J&K. *International Journal of Scientific Research* **2**(6): 304-3063.

Kumar PS, Rabindra RJ and Ellison CA. 2008. Expanding classical biological control of weeds with pathogens in India: the way forward. *Proceedings XII International Sympoium on Biological Control of Weeds*, La Grande Motte, France.

Kumari Preeti, Pankaj K, Sahu Madhu, Soni Y and Poonam Awasthi. 2014. Impact of *Parthenium hysterophorus* L. invasion on species diversity of cultivated fields of Bilaspur (C.G.) *Indian Agricultural Sciences* **5**(8): 754-764.

Kumar S and Rohatgi N. 1999. The role of invasive weeds in changing floristic diversity. *Annals of Forestry* **7**: 147,150.

Lonkar A, Mitchell JC and Calman CD. 1974. Contact dermatitis from *Parthenium hysterophorus*. *Transactions of the St. John's Hospital Dermatological Society* **60**: 43-53.

Mahadevappa M. 2009. *Parthenium*: *Insight into its Menace and Management*. Stadium Press, Pvt. Ltd, New Delhi, India: 178 p.

Maharjan S, Shrestha BB, Jha PK. 2007. Allelopathic effects of aqueous extract of leaves germination and seedling growth of some of *Parthenium hysterophorus* L. on seed cultivated and wild herbaceous species. *Scientific World***.** **5**(5): 33- 39.

Maiti GS. 19983. An untold study on the occurrance of *Parthenium hysterophorus* L. in India. *Indian Journal of Forestry* **6**: 328-329.

Mane JD, Jadav SJ and Ramaiah NA. 1986. Production of oxalic acid from dry Powder of *Parthenium hysterophorus L. Journal of Agricultural Food Chemistry* **34**: 1989-1990.

Marwat KB, Hashim S and Ali H. 2010. Weed management: A case study from North-West Pakistan. *Pakistan Journal Botany* **42**: 341–353

McConnachie AJ, Strathie LW, Mersie W, Gebrehiwot L and Zewdie K Abdurehim A. 2011. Current and potential geographical distribution of the invasive plant *Parthenium hysterophorus* (Asteraceae) in Eastern and Southern Africa. *Weed Research* **51**: 71-84.

McFadyen RC. 1985. Biological control against *Parthenium* weed in Australia. *Crop Protection* **11**: 400-407.

McFadyen RE. 1995. *Parthenium* weed and human health in Queensland. *Australian Family Physician* **24**(8): 1455-1458.

Mishra JS and Bhan VM. 1996. Chemical control of carrot grass (*Parthenium hysterophorus*) and associated weeds in soybean (Glycine max).*Indian Journal of Agricultural Science* **66**: 518-521.

Mishra KK. *Parthenium hysterophorus* L.- a new record for Nepal. *Journal of Bombay Natural History Society* **88**: 466-467.

Morales-Payan JP, Santos BM, Stall WM and Bewick TA. 2000. Influence of nitrogen fertilization on the competitive interactions of cilantro (*Coriandrum sativum*) and purple nutsedge (*Cyperus rotundus*). *Journal of Herbs Spices and Medicinal Plants* **6**: 59-66.

Naidu VSGR and Paroha Seema. 2008. Growth and biomass partitioning in two weed species, *Parthenium hysterophorus* (C3) and *Amaranthus viridis* (C4), under elevated CO_2. *Ecology, Environment and Conservation* **14**(4): 515-518.

Naidu VSGR, Paroha Seema, Yaduraju NT and Nayak Siddarth. 2007. Seed born toxicants control germination and viability in *Parthenium hysterophorus* L. seeds. *Ecology, Environment and Conservation* **13**(1): 67-70.

Naidu. 2013. Invasive potential of C3-C4 intermediate Parthenium hysterophorus under elevated CO2. *Indian Journal of Agricultural Sciences* **83**(2): 176-179

Naidu VSGR and Murthy TGK. 2014. Crop-weed interactions under climate change. *Indian Journal of Weed Science* **46**(1): 61-65.

Nath R. 1988. Note on the effect of *Parthenium* extract on seed germination and seedling growth in crops. *Indian Journal of Agricultural Science* **51**: 601-603.

Navie S. 2003. *The biology of Parthenium hysterophorus L.* in Australia. PhD Thesis, The University of Queensland, Brisbane, Australia.

Navie SC, McFadyen RE, Panetta FD and Adkins SW. 1998. The biology of Australian weeds. *Parthenium hysterophorus* L. *Plant Protection Quaterly* **11**: 76-88.

Navie SC, Panetta FD, McFadyen RE and Adkins SW. 1996. Behaviour of buried and surface-sown seeds of *Parthenium hysterophorus*. *Weed Research* **38**: 335-341.

Navie SC, Priest TE, McFadyen RE and Adkins SW. 1998. Efficacy of the stemgalling moth *Epiblema strenuana* Walk. (Lepidoptera: Tortricidae) as a biological control agent for ragweed *Parthenium* (*Parthenium hysterophorus* L.). *Biological Control* **13**: 1-8.

Navie S, Shabbir A and Adkins Steve (Eds). 2010. *International Parthenium News* No. 1, January 2010

Nigatu L, Hassen A, Sharma J and Adkins SW. 2010. Impact of *Parthenium hysterophorus* on grazing land communities in North-Eastern Ethiopia. *Weed Biology and Management* **10**: 143-152.

Pandey DK. 1996. Phytotoxicity of sesquiterpene lactone parthenin on aquatic weeds. *Journal of Chemical Ecology* **22**: 151-160.

Pandey DK, Palni LMS and Joshi SC. 2003. Growth, reproduction, and photosynthesis of ragweed *Parthenium* (*Parthenium hysterophorus*). *Weed Science* **51**(2):191-201.

Pandey AK, Singh AK, Quereshi S, and Wahab S. 2005. Microbial management of *Parthenium hysterophorus* in Madhya Pradesh: current status, pp. 102-106. In: *Proceedings of Second International Conference on Parthenium Management* held at Bangalore (Karnataka), 5-7 December, 2005.

Pandey RK and Saini S K. 2002. *Parthenium* threat to biological diversity of natural forest ecosystem in Madhya Pradesh. *Vaniki Sandesh* 26 (2): 21-29

Parsons WT and Cuthbertson EG. 1992. *Noxious weeds of Australia*. Inkata Press, Melbourne/Sydney, Australia: 692 p.

Paredes E and Labrada R. 1986. Umbral de daños de *Parthenium hysterophorus* en plantación de pimiento y siembra directa de tomate. *Resumenes VIII Congreso ALAM, Guadalajara,* p 37.

Patil RR. 1997. Phagostimulant effects of *Parthenium* on mulberry silkworm (*Bombyx mori* L.), pp. 81-85. In: *Proceedings of the First International Conference on Parthenium Management,* (Eds. Mahadevappa M and Patil VC), Dharwad, India, 6-9 October 1997. Dharwad, India: University of Agricultural Sciences.

Rahman A, Alam Ms, Khan Sk.2008. Taxonomic studies on the family Asteraceae (Compositae) of the Rajshahi division. *Research Journal of Agriculture and Biological Sciences* (Bangladesh) **4**: 134–140.

Ramaswami PP. 1997. Potential uses of *Parthenium*. pp. 77-80. In *First International Conference on Parthenium Management* held at Dharwad (Karnataka), 6-8 October 1997, (Eds. Mahadevappa M. and Patil VC), Volume I.

Ranade S. 1976. Result of newly synthesized vaccine in case of congress grass eczema in India. Paper read at "Aswini" Naval base hospital, Bombay (Mumbai).

Rao RS. 1956. *Parthenium*, a new record for India. *Journal Bombay Natural History Society* **54**: 218-220.

Roxburgh W. 1914. *Hortus Bengalensis*, Misson Press Calcutta.

Rajulu SG, Gowri N and Perumal, NS. 1976. Biologial control of the pernicious weed *Parthenium hysterophorus* Linn. *Current Science* 45: 624-625.

Shabbir A and Bajwa R. 2006. Distribution of *Parthenium* weed (*Parthenium hysterophorus* L.), an alien invasive weed species threatening the biodiversity of Islamabad.*Weed Biology and Management* **6**: 89-95.

Shabbir A, Dhileepan K, O'Donnell C and Adkins SW. 2013. Complementing biological control with plant suppression: implications for improved management of *Parthenium* weed (*Parthenium hysterophorus* L.). *Biological Control* **64**: 270-275.

Shabbir A. 2012. *Towards the improved management of Parthenium weed: complementing biological control with plant suppression*. PhD Thesis, The University of Queensland, Brisbane, Australia.

Shrestha Bharat Babu. 2012.*Parthenium* weed in Chitwan National Park, Nepal. *International Parthenium News Letter,* 5: 8-9.

Singh HP, Batish DR, Pandher JK and Kohli RK. 2005. Phytotoxic effects of *Parthenium hysterophorus* residues on three *Brassica* species.*Weed Biology and Management* **5**: 105-109.

Singh NP. 1983. Potential biological control of *Parthenium hysterophorus* L.*Current Science* **52**: 644.

Singh Neelu and Sushilkumar. 2004.Antifeedant activities of parthenin,isolated from *Parthenium hysterophorus* against forest pests. *Annals of Entomology* 22(1&2): 55-57.

Singh, SP. 1989. *Biological suppression of weeds*. NCIPM, Faridabad: *Technical Bulletin No*.1. 15-16.

Singh SP. 1993. Integrated management of *Parthenium*. *Proceedings of International Symposium*, Indian Society Weed Science, Hissar Nov. 18- 20 1993, Vol.I: 393-398.

Sridhar S. 1991. A cure no more, under attack the sunflower crop. *Frontline* Madras. Nov., 9-22: p. 100.

Sriramarao P, Nagpal S, Subba Rao BS, Prakash O and Subba Rao PV. 1991. Immediate hypersensitivity to *Parthenium hysterophorus* II. Clinical studies on the prevalence of *Parthenium* rhinitis. *Clinical Experimental Allergy* **21:** 55-62.

Strathie LW, McConnachie AJ and Retief E. 2011. Initiation of biological control against *Parthenium hysterophorus* L. (Asteraceae) in South Africa. *African Entomologist* **19**: 378-392.

Sushilkumar. 2005. *Biological control of Parthenium through Zygogramma bicolorata*. National Research Centre for Weed Science, Jabalpur, India: 88p.

Sushilkumar. 2006. Economic benefits in biological control of parthenium by Mexican beetle, *Zygogramma bicolorata* pallister (Coleoptera: Chrysomelidae) in India. *Annals of Entomology* **24**(1&2): 75-78.

Sushilkumar. 2009. Biological control of *Parthenium* in India: status and prospects. *Indian Journal of Weed Science* **41**(1&2): 1-18.

Sushilkumar. 201. Integrated managment of *Parthenium*. Extension folder, Directorate of Weed Science Research.6 p.

Sushilkumar. 2012. Current spread, impact and management of *Parthenium* weed in India. *International Parthenium News* **5**: 1-6.

Sushilkumar. 2013. Weed problems in protected areas and prospects of their management, pp. 105-116. In: *Proceedings of National Workshop on Grassland Management in Protected Areas in India*: *Prospects and retrospect.* 4-6 July 2013, Bandhavgarh Tiger Reserve, Madhya Pradesh, Organized by State forest Research nstitute, Jabalpur.

Sushilkumar and Bhan VM. 1996. Parthenium control by insects in India: retrospects and prospects. *Journal of Applied Zoological Researches* **6**(2): 109-115.

Sushilkumar and Bhan VM. 1997. Natural parthenium replacement by *Cassia tora* at Jabalpur and adjoining areas of Madhya Pradesh, India.*Proceedings of 1st International Conference on Parthenium Management*. University of Agricultural Sciences, Dharwad. 6-8 October, 1997.

Sushilkumar and Ranganatha ARG. 2011. *Community Approach for Parthenium management: A Report of Parthenium Awareness Week -2011*. 48 p.

Sushilkumar and Ray P. 2010. Activity enhancement of *Zygogramma bicolorata*, a biocontrol agent of *Parthenium hysterophorus*, by temperature regulated diapause aversion. *Biocontrol Science and Technology* **20**(9): 903-908.

Sushilkumar and Ray P. 2011. Evaluation of augmentative release of *Zygogramma bicolorata* Pallister (Coleoptera: chrysomelidae) for biological control of *Parthenium hysterophorus* L. *Crop Protection* **30**: 587-591.

Sushilkumar and Saraswat, V.N. 2001. Integrated management: The only solution to suppress *Parthenium hysterophorus*, pp.150-168. In: *Alien Weeds in Moist Tropical Zones: Banes and Benefits*," (Eds. KV Sankaran, ST Murphy and HC Evans) Workshop Proceedings, 2-4 November, 1999, Kerala, India, Kerala Forest Research Institute, India and CABI Bioscience, UK Centre (Ascot), UK.

Sushilkumar and Sharma AR. 2012. *Creating Awarness on Parthenium Management: A Report on Parthenium Awareness Week*: 50 p.

Sushilkumar and Varshney JG. 2007. *Gajarghas ka jaivik niyantrana: Vartman sthathi and sambhavnaie* (in Hindi) [Biological control of *Parthenium*: current status and prospects], 157 p.

Sushilkumar and Varshney J.G. 2010. *Parthenium* infestation and its estimated cost management in India. *Indian Journal of Weed Science* **42**(1&2): 73-77.

Sushilkumar, Yaduraju NT, Vishwakarma K and Sondhia S. 2005. Nutrient quality and seed viability of parthenium compost by NADEP and conventional pit method. In: *2nd International Confrence on Parthenium Management*. Bangalore. December 5-7, 2005.

Tamado T, Ohlander L and Milberg P. 2002. Interference by the weed *Parthenium hysterophorus* L. with grain sorghum: influence of weed density and duration of competition. *International Journal of Pest Management* **48**: 183-188.

Tang SQ, Wei F, Zeng LY, Li XK, Tang SC, Zhong Y and Geng YP. 2009. Multiple introductions are responsible for the disjunct distributions of invasive *Parthenium hysterophorus* in China: evidence from nuclear and chloroplast DNA. *Weed Research* **49**: 373-380.

Taneja K, Jain PP and Naithani S. 1997. Utilization of *Parthenium hysterophorus* (Gajar grass) and *Circium* species as paper raw material. *World Weeds* **4**: 21-23.

Timsina B, Shrestha BB, Rokaya MB and Munzbergova Z. 2011. Impact of *Parthenium hysterophorus* L. invasion on plant species composition and soil properties of grassland communities in Nepal.Flora (Jena) **6**: 233-240.

Tudor GD, Ford AL, Armstrong TR and Bromage EK. 1982. Taints in meat from sheep grazing *Parthenium hysterophorus*. *Australian Journal of Expermental Agricultural and Animal Husbandry* **22**: 43-46.

Varshney JG and Sushilkumar. 2006. *A Rport on Parthenium Awareness Week* 56 p.

Varshney JG. and Sushilkumar. 2007. *People Participatory Approach to Manage Parthenium: A report on Parthenium Awareness Week.* 62 p.

Varshney Jay G. and Sushilkumar. 2008. *Community approach for Parthenium Management: a report on Awareness Week-2008*. 60 p.

Varshney JG and Sushilkumar. 2009. *Motivation approach for Parthenium Management: A Report on Awareness Week-2009*. 53 p.

Varshney JG and Sushilkumar. 2010. *Marching Ahead for Parthenium Management: A Report on Awareness Week-2009*. 59 p.

Varshney JG and Sushilkumar. 2010. *Parthenium-converting the curse to boon. 3rd International Conference on Parthenium*. Indian Agricultural Reserach Institute, New Delhi. December 8-10, 2010.

Vertak VD. 1968. Weed that threatens crop and grasslands in Maharashtra. *Indian Farming* **18**: 23-24.

Vogler W, Navie S and Adkins SW. 2002. Use of fire to control *Parthenium* weed. *A report for the Rural Industries Research and Development Corporation*, Australia.

White GG. 1994. *Parthenium Weed*. Corporative Research Centre for Tropical Pest Management, Brisbane, Australia.

Yaduraju NT, Sushilkumar, Prasad Babu, MBB and Gogoi AK. 2005. *Parthenium hysterophorus* - Distribution, problem and management strategies in India, pp. 6-10. *In: Proceedings of Second International Conference on Parthenium Management* held at GKVK, Bangalore (Karnataka), 2005.

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Weed management by herbicide combinations in transplanted rice

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ABSTRACT

Field experiments were conducted in transplanted rice at Visva-Bharati, Sriniketan during *Kharif* seasons of 2012 and 2013. The predominant weed species were: *Ludwigia parviflora*, C*yanotis axillaris*, *Commelina diffusa* and *Spilanthes acmella*. Pre-emergence application of pretilachlor + bensulfuron at 660 g/ha and post-emergence application of bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl at 4 g/ha effectively controlled grassy weed population. Post-emergence application of bispyribac + metsulfuron-methyl + chlorimuron-ethyl was found to be most effective in controlling broad-leaved weeds and it was closely *fb* bispyribac + ethoxysulfuron applied as post-emergence. Application of bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl as post-emergence and pyrazosulfuron-ethyl as pre-emergence were effective in controlling sedge population. Post-emergence application of bispyribac + ethoxysulfuron, pretilachlor *fb* metsulfuron-methyl + chlorimuron-ethyl, pyrazosulfuron *fb* manual weeding, pretilachlor + bensulfuron and weed-free check recorded more grain yield. The highest net returns and B:C ratio were recorded with bispyribac + metsulfuron-methyl + chlorimuron-ethyl and pre-emergence application of pretilachlor *fb* metsulfuron-methyl + chlorimuron-ethyl. Herbicides applied in combination recorded more net returns and B:C ratio as compared to sole application of herbicides.

Key words: Economics, Herbicides combination, Transplanted rice, Weed management

Rice is the world's most important food among all staple food crops and more than half of the world's population depends on rice for food, calories and protein, especially in developing countries. Like other cereal crops, rice also suffers severly from weed competitions (Rao *et al.* 2007). Uncontrolled weeds compete with rice and cause yield losses to the tune of 50-65% under wet-seeded rice (Subbaiah and Sreedevi 2000) and up to 76% in transplanted rice (Singh *et al.* 2004). The farmers generaly do 2-3 hand weedings in transplanted rice. Post-emergence application of metsulfuron-methyl + chlorimuron-ethyl and early post-emergence application of ethoxysulfuron showed promising results in achieving more grain yield of transplanted rice (Pal *et al.* 2008). Pre-emergence application of pyrazosulfuron, penoxulam (Chauhan and Seth 2013) and post-emergence bispyribac (Khaliq *et al.* 2012) herbicides were considered to be an alternative/supliment to hand weeding. Therefore, the present experiment was conducted to find out the effective herbicides or herbicide mixtures for weed control in transplanted rice.

MATERIALS AND METHODS

The field experiments were conducted in Agricultural Farm of Institute of Agriculture, Visva-Bharati, Sriniketan during *Kharif* seasons of 2012 and 2013. The soil was sandy loam, slightly acidic in nature with medium N and P and low in K. The experiment was laid out in randomized block design with 10 treatments and 3 replications. The rice variety '*IR-64*' was transplanted. The treatments were bispyribac-sodium 25 g/ha at 20 DAT, pretilachlor 1000 g/ha at 3 DAT, penoxsulam 22.5 g/ha at 10 DAT, pyrazosulfuron 20 g/ha at 3 DAT, bispyribac + ethxy-sulfuron 25 + 18.75 g/ha at 25 DAT, bispyribac-sodium + metsulfuron-methyl + chloromuron-ethyl (20 + 4) g/ha at 25 DAT, pretilachlor at 750 g/ha at 3 DAT *fb* ethoxy-sulfuron 18.75 g/ha at 25 DAT, pretilachlor 750 g/ha at 3 DAT *fb* metsulfuron-methyl + chloromuron-ethyl 4 g/ha + bensulfuron 660 g/ha at 5 DAT. Weed free check (hand weeding at 25 and 45 DAT) and weedy check were also included. The weed density, weeds biomass, crop growth parameters, yield and yield attributes were recorded.

RESULTS AND DISCUSSION

Weed flora

During 2012, the experimental rice field was infested with 18 weed species out of which 4 grasses, 12 broad-leaved and 2 sedges were recorded but in *Kharif* 2013, 17 weeds species prevailed in the experimental field, out of which there were 4 grasses, 11 broad-leaf and 2 sedges. The pre-dominant weed species were *Ludwigia parviflora*, C*yanotis axillaris*, *Commelina diffusa* and *Spilanthes acmella*.

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Effect on weeds

Among the different herbicidal treatments, pretilachlor + bensulfuron 660 g/ha as pre-emergence and bispyribac + metsulfuron-methyl + chlorimuron-ethyl as post-emergence effectively controlled grassy weed density (Table 1). This treatment was statistically at par with bispyribac + ethoxysulfuron 25 + 18.75 g/ha applied at 25 DAT during *Kharif* 2012. During *Kharif* 2013, in addition to above, herbicides combinations, pyrazosulfuron followed by (*fb*) manual weeding also showed best performance in controlling grassy weeds. Post-emergence application of bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl was found to be most effective against broad-leaved weeds and it was closely *fb* bispyribac-sodium + ethoxysulfuron applied as post-emergence. Application of bispyribac-sodium + metsulfuron-methyl +chlori-muron-ethyl as post-emergence and pyrazosulfuron-ethyl as pre-emergence were found effective in controlling sedges. Regarding suppression of total weed density, post-emergence application of bispyribac-soidum + metsulfuron-methyl + chlorimuron-ethyl was found to be most effective and this was closely *fb* bispyribac-sodium + ethoxysulfuron as post-emergence and pretilachlor *fb* metsulfuron-methyl + chlorimuron-ethyl. The sole application of bispyribac-sodium, pretilachlor and pyrazosulfuron were found comparatively less effective in reducing the weeds density. Similar trend was also noticed with biomass of grass, broad-leaved and total weeds.

Effect on crop

There were significant differences on rice height, density and biomass at 60 DAT. During both the years, highest number of rice plant population/m^2 was noticed with post-emergence application of bispyribac-spodium + ethoxysulfuron which was closely *fb* bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl, pretilachlor *fb* metsulfuron-methyl + chlorimuron-ethyl, pyrazosulfuron *fb* manual weedings, pretilachlor + bensulfuron and weed free check . At 60 DAT, crop biomass was highest in weed free check and this was closely *fb* bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl, bispyribac-soidum + ethoxysulfuron, pretilachlor *fb* ethoxysulfuron/ metsulfuron-methyl + chlorimuron-ethyl and pyrazosulfuron *fb* manual weeding.

Effect on yield

Among the yield attributes, number of effective tillers/m^2 and number of grains/panicle differed significantly but there were no significant differences in test weight during both the years. Post-emergence application of bispyribac + metsulfuron-methyl + chlorimuron-ethyl produced highest number of effective tillers and number of grains/panicle and this was closely *fb* bispyribac + ethoxysulfuron, pretilachlor *fb* metsulfuron-methyl + chlorimuron-ethyl, pyrazosulfuronfb manual weeding, pretilachlor + bensulfuron and weed free check.

Table 1. Effect of treatments on weed density at 60 DAT

Treatment	Weed density/m^2							
	Grasses		Broad-leaved weeds		Sedges		Total	
	2012	2013	2012	2013	2012	2013	2012	2013
Bispyribac	2.8 (7.3)	2.8 (7.7)	6.9 (47.3)	6.2 (38.3)	2.0 (3.7)	2.3 (4.7)	7.7 (58.3)	7.1 (50.7)
Pretilachlor	1.7 (2.3)	1.9 (3.0)	9.1 (82.3)	8.5 (72.3)	2.5 (6.0)	2.9 (7.7)	9.5 (90.7)	9.1 (83.0)
Penoxsulam	2.5 (5.7)	2.7 (7.0)	6.1 (37.0)	6.0 (35.3)	1.7 (2.3)	1.8 (2.7)	6.7 (45.0)	6.7 (45.0)
Pyrazosulfuron	2.3 (4.7)	2.6 (6.3)	8.9 (79.3)	9.4 (88.0)	0.7 (0.0)	0.7 (0.0)	9.2 (84.0)	9.7 (94.3)
Bispyribac + ethoxysulfuron	1.3 (1.3)	1.7 (2.3)	4.1 (16.7)	4.7 (21.7)	1.6 (2.0)	1.7 (2.3)	4.5 (20.0)	5.2 (26.3)
Bispyribac + metsulfuron-methyl + chlorimuron-ethyl	0.7 (0.0)	0.7 (0.0)	3.7 (13.7)	3.5 (11.7)	0.7 (0.0)	0.7 (0.0)	3.7 (13.7)	3.5 (11.7)
Pretilachlor *fb* ethoxysulfuron	1.6 (2.3)	1.8 (2.7)	6.8 (46.0)	6.4 (40.7)	2.3 (5.0)	2.4 (5.3)	7.3 (53.3)	7.0 (48.7)
Pretilachlor *fb* metsulfuron-methyl + chlorimuron-ethyl	2.8 (7.3)	2.8 (7.3)	4.7 (22.0)	4.4 (19.7)	1.9 (3.0)	2.0 (3.7)	5.7 (32.3)	5.6 (30.7)
Pyrazosulfuron *fb* manual weeding	0.7 (0.0)	0.7 (0.0)	6.8 (46.0)	6.9 (47.3)	0.7 (0.0)	0.7 (0.0)	6.8 (46.0)	6.9 (47.3)
Pretilachlor + bensulfuron	0.7 (0.0)	0.7 (0.0)	5.9 (34.0)	5.5 (29.3)	2.0 (3.3)	2.3 (4.7)	6.1 (37.3)	5.9 (34.0)
Weed free	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)
Weedy check	11.2 (124)	11.1 (123)	14.3 (205)	14.7 (214)	7.2 (51.7)	8.5 (72)	19.5 (380)	20.3 (410)
LSD (P=0.05)	0.6	0.5	0.8	0.9	0.4	0.4	0.8	0.9

Figures in the parentheses indicate the actual values, data subjected to square root transformation, transformed value = $\sqrt{x + 0.5}$

Table 2. Effect of treatments on weed biomass at 60 DAT

Treatment	Weed biomass (g/m^2)							
	Grasses		Broad-leaved weeds		Sedges		Total	
	2012	2013	2012	2013	2012	2013	2012	2013
Bispyribac	1.5(1.8)	1.5(1.9)	3.0(8.4)	2.9(7.7)	1.6(2.0)	1.6(2.0)	3.5(12.1)	3.5(11.6)
Pretilachlor	1.4(1.4)	1.5(1.8)	3.1(9.0)	3.4(10.8)	1.4(1.4)	1.5(1.7)	3.5(11.8)	3.8(14.3)
Penoxsulam	1.3(1.3)	1.3(1.2)	2.8(7.1)	2.7(6.8)	1.2(1.0)	1.2(0.9)	3.1(9.4)	3.0(8.9)
Pyrazosulfuron	1.1(0.8)	1.1(0.8)	3.6(12.5)	3.9(15.0)	0.7(0.0)	0.7(0.0)	3.7(13.3)	4.0(15.8)
Bispyribac + ethoxysulfuron	1.0(0.5)	1.0(0.5)	1.6(2.0)	2.0(3.4)	1.6(2.0)	1.5(1.6)	2.2(4.6)	2.5(5.6)
Bispyribac + metsulfuron-methyl + chlorimuron-ethyl	0.7(0.0)	0.7(0.0)	1.4(1.5)	1.5(1.7)	0.7(0.0)	0.7(0.0)	1.4(1.5)	1.5(1.7)
Pretilachlor *fb* ethoxysulfuron	1.2(1.1)	1.2(1.0)	2.6(6.4)	2.8(7.6)	1.8(2.6)	1.8(2.9)	3.3(10.2)	3.4(11.5)
Pretilachlor *fb* metsulfuron-methyl + chlorimuron-ethyl	1.9(3.4)	2.2(4.2)	1.5(1.8)	1.5(1.9)	1.2(1.0)	1.4(1.4)	2.6(6.2)	2.8(7.5)
Pyrazosulfuron *fb* manual weeding	0.7(0.0)	0.7(0.0)	2.4(5.4)	2.5(6.0)	0.7(0.0)	0.7(0.0)	2.4(5.4)	2.5(6.0)
Pretilachlor + bensulfuron	0.7(0.0)	0.7(0.0)	2.2(4.4)	2.5(5.7)	2.0(3.5)	2.2(4.3)	2.9(7.9)	3.2(10.0)
Weed free	0.7(0.0)	0.7(0.0)	0.7(0.0)	0.7(0.0)	0.7(0.0)	0.7(0.0)	0.7(0.0)	0.7(0.0)
Weedy check	3.9(15.0)	4.6(21.1)	9.3(87.0)	9.9(96.9)	2.8(7.3)	3.5(11.5)	10.5(109)	11.4(129)
LSD (P=0.05)	0.4	0.3	0.4	0.5	0.3	0.3	0.4	0.6

Figures in the parentheses indicate the actual values

Table 3. Effect of treatments on crop growth at 60 DAT, yield and yield of rice

Treatment	Plant height (cm)		Plant population/m^2		Biomass (g/m^2)		Effective tillers/m^2		No. of grains/panicle		Grain yield (t/ha)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Bispyribac	107	106	410	411	572	322	315.0	69.3	69.3	72.7	4.62	4.45
Pretilachlor	102	104	397	399	581	305	296.7	65.0	65.0	69.0	4.39	4.16
Penoxsulam	102	106	402	405	583	305	296.0	67.3	67.3	61.3	4.38	4.15
Pyrazosulfuron	102	102	373	376	609	313	291.0	67.7	67.7	61.7	4.50	4.31
Bispyribac + ethoxysulfuron	102	103	455	451	672	350	353.3	78.7	78.7	75.0	5.03	4.83
Bispyribac + metsulfuron-methyl + chlorimuron-ethyl	98	103	450	448	715	364	362.7	84.0	84.0	83.7	5.23	5.12
Pretilachlor *fb* ethoxysulfuron	103	105	407	400	665	318	298.3	73.3	73.3	68.7	4.57	4.37
Pretilachlor *fb* metsulfuron-methyl + chlorimuron-ethyl	98	99	442	439	635	347	346.7	75.7	75.7	74.3	5.06	4.81
Pyrazosulfuron *fb* manual weeding	106	105	437	431	670	347	336.7	72.7	72.7	69.0	4.96	4.76
Pretilachlor + bensulfuron	99	101	433	429	605	338	329.3	73.3	73.3	67.0	4.93	4.71
Weed free	104	104	447	437	729	360	353.3	82.3	82.3	79.3	5.17	4.80
Weedy check	102	99	372	363	504	248	242.3	56.7	56.7	58.3	3.57	3.27
LSD (P=0.05)	6.8	3.5	35.1	53.6	96.9	76.7	32.2	48.4	7.6	13.5	0.46	0.81

Post-emergence application of bispyribac + metsulfuron-methyl + chlorimuron-ethyl recorded the highest grain yield (5.12 t/ha). Post-emergence application of bispyribac + ethoxysulfuron (4.83 t/ha), pretilachlor *fb* metsulfuron- methyl + chlorimuron-ethyl (4.81 t/ha), pyrazosulfuron *fb* manual weeding (4.76 t/ha), pretilachlor + bensulfuron (4.71 t/ha) and weed free (4.80 t/ha) check recorded more grain yield and these were at par with the best treatment. The sole application of bispyribac sodium, pretilachlor and pyrazosulfuron produced less grain yield. Early post-emergence of penoxsulam also produced lower grain yield due to its phyto toxic effect on crop. The lowest grain yield (3.265 t/ha) was recorded under weedy check.

Table 4. Effect of different weed control treatments on economics

Treatment	Cost of cultivation (x10^3 `/ha)	Gross returns (x10^3 `/ha)	Net returns (x10^3 `/ha)	B:C ratio
Bispyribac	26.80	59.41	32.61	2.22
Pretilachlor	25.10	56.01	30.91	2.23
Penoxsulam	25.90	55.85	29.95	2.16
Pyrazosulfuron	24.90	57.73	32.83	2.32
Bispyribac + ethoxysulfuron	27.50	64.55	37.05	2.35
Bispyribac + metsulfuron-methyl + chlorimuron-ethyl	26.70	67.73	41.04	2.54
Pretilachlor *fb* ethoxysulfuron	26.00	58.57	32.57	2.25
Pretilachlor *fb* metsulfuron-methyl + chlorimuron-ethyl	25.70	64.65	38.95	2.52
Pyrazosulfuron *fb* manual weeding	26.90	63.68	36.78	2.37
Pretilachlor + bensulfuron	25.60	63.14	37.54	2.47
Weed free	29.20	65.27	36.07	2.24
Weedy check	23.60	44.74	21.14	1.90
LSD (P=0.05)	-	6.43	6.43	0.25

Price of rice – ` 13,100/t

Post-emergence application of tank-mix of bispyribac-sodium at 20 g + metsulfuron-methyl + chlorimuron-ethyl 4 g/ha and pre-emergence application of pretilachlor at 750 g *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha has been found effective in controlling weed population and achieving higher profitability in transplanted rice.

Economics

The highest net returns (` 41,036/ha) and B:C ratio (2.54) was recorded under bispyribac + metsulfuron-methyl + chlorimuron-ethyl. Pretilachlor *fb* metsulfuron-methyl + chlorimuron-ethyl also recorded higher net return (` 38,953/ha) and B:C ratio (2.52). Due to high weeding cost in weed free check, the net return (` 36,073/ha) and B:C ratio (2.24) were narrow. The herbicides applied in combination recorded more net returns and B:C ratio compared to sole application of herbicides.

REFERENCES

Chauhan BS and Seth BA. 2013. Weed management in mechanized-sown, zero-till dry-seeded rice. *Weed Technology* **27**(1): 28-33.

Khaliq A, Matloob A, Ahmad N, Rasul F and Awan IU. 2012. Post-emergence chemical weed control in direct-seeded fine rice. *Journal of Animal and Plant Sciences* **22**(4): 1101-1106.

Pal D, Dolai AK, Ghosh RK, Mallick S, Mondal D and Barui K. 2008. Bio-efficacy and phyto-toxicity of ethoxysulfuron on the weed control and yield performance of transplanted rice in the gangetic alluvial soil of West Bengal. *Journal of Crop and Weed* **4**(1): 38-40.

Rao AN, Mortimer AM, Johnson DE, Sivaprasad B and Ladha JK. 2007. Weed management in direct-seeded rice. *Advances in Agronomy* **93**: 155-257.

Singh VP, Govindra Singh and Mahendra Singh. 2004. Effect of fenoxaprop-ethyl on transplanted rice and associated weeds. *Indian Journal of Weed Science* **36**: 190-192.

Subbaiah SV and Sreedevi B. 2000. Efficacy of herbicide mixtures in weed control in direct-secded rice under puddle conditions. *Indian Journal of Weed Science* **32**: 199-200.

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Weed dynamics and system productivity under rice-based cropping system

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ABSTRACT

An experiment was carried out during 2008-09 and 2009-10 at Jagdalpur, Chhattisgarh to determine the influence of rice-based cropping system on the weed dynamics. The rice-fallow system had the higher density (1364 and 1435/m^2) of *Echinochloa colona,* which was gradually reduced with increasing cropping intensity and the lowest density was under rice-garden pea system (20.0 - 20.9/m^2). Increasing irrigation frequency increased the density of *E. colona*. In *Rabi* season, rice-wheat and rice-garden pea cropping systems were found highly infested with weeds as compared to rice-fallow, rice-chickpea and rice-summer maize systems. The highest rice equivalent yield was recorded under rice-chickpea (7.20-7.76 t/ha) cropping system.

Keywords: Cropping system, System productivity, Weed density, Weed dynamics

Rice production constitutes the major economic activities and key source of livelihood for the rural households of Southern Chhattisgarh. In Chhattisgarh, rice occupies average of 3.6 million ha with the productivity ranging between 1.2-1.6 t/ha depending upon the rainfall. The state is popularly recognized as rice bowl of the country as rice is the principal crop and about 69.7% of net sown area is covered under *Kharif* rice. Fallowing of lands is common but recent demand of food security leads to take succeeding crops in system to make it profitable. However, some farmers do grow winter crops like wheat, garden pea, chickpea, summer maize depending on the irrigation facilities available. Weed infestation in field increases demand for available resources management of weeds is of paramount importance in all respect to achieve desirable yield. But, labour engagement for weeding is costly because of non-availability of labours in time which leads farmers to use herbicides. Weed dynamics vary largely due to cropping system and moisture availability and reduce crop yields ranging from 30 to 100% in wheat, 20 to 60 % in chickpea 10 to 45% (Pradhan *et al.* 2014). There is urgent need to combat the weed infestation in cropping system to increase the system productivity.

MATERIALS AND METHODS

The field experiment was conducted during 2008-09 and 2009-10 at S.G. College of Agriculture and Research Station, Jagdalpur (Chatttisgarh). The soil was sandy loam in texture, low in organic carbon (0.43%) available N (178 kg/ha) and available phosphorus (21.4kg/ha) and medium in available potassium (179 kg/ha) with normal in reaction (pH 6.8). The experiment was laid out in a split-plot design by keeping five cropping systems, *viz.* rice-fallow, rice-wheat, rice-garden pea, rice-chickpea and rice-summer maize) in main plots and three irrigation levels, *viz.* 2, 4 and 6 irrigation frequency in sub-plots repeating four times. Transplanting of rice seedlings was done on 26 July, 2008 and 20 July, 2009 and harvested on 2 December, 2008 and 30 November, 2009, respectively.

The succeeding winter crops were sown after harvest of rice. Summer maize was sown during the first week of January. Recommended package of practices of the region except irrigation was adopted for all the crops. The irrigation frequency was maintained equally for each crop as 2 irrigations (at sowing and before flowering stage), 4 irrigations (at sowing, tillering/branching, before flowering and milking stage) and 6 irrigations (at sowing, tillering/branching, late tillering, flowering, milking and dough stages). Chickpea crop was also irrigated two times to homogenize the treatment affects. Weed sample were collected by random placing of 50 x 50 cm quadrate in each plot at monthly interval. Weeds were cut down at ground levels and then identified, counted and the samples were kept in an oven at 70 ± 1 ^{o}C until they attained constant weight. The crop growth and yield attributing characters were also recorded at different stages of crop. The data on weeds were transformed with square root transformation $\sqrt{x + 0.5}$ for statistical analysis.

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RESULTS AND DISCUSSION

Density of weeds

Different cropping system had significant effect on density of weeds during different seasons. In rice-fallow cropping system, higher density of *Echinochloa colona* was recorded which, reduced gradually with increasing cropping intensity. The lowest density of *Echinochloa colona* was noticed under rice-garden pea system (20.0/m^2 and 20.9/m^2) during both the years of experimentation. The irrigation frequency also showed significant impact on dynamics of weed density having higher density with more number of irrigation frequencies while, two irrigations had lower density of *Echinochloa colona* which, was increased upto six irrigations (26.0 and 27.2/m^2). Both the cropping systems reduced the density of *Echinochloa colona* whereas irrigation frequency increased the density of weeds. *Cyperus iria* was also suppressed by cropping system, but no significance difference in density of *C. iria* under rice-fallow, rice-wheat, rice-chickpea and rice-summer maize was recorded. The rice-garden pea attained lower density of *Cyperus iria* (16.7/m^2).

In *Rabi* season, some prominent weeds were *Chenopodium album*, *Medicago denticulata*, *Polygonum plebieum*, *Echinochloa colona* and *Medicago alba.* Among the cropping systems, rice-wheat and rice-garden pea cropping systems were found infested with high number of *Rabi* season weeds as compared to rice-fallow, rice-chickpea and rice-summer maize system of cropping. *Chenopodium album, Medicago denticulata, Polygonum plebieum, Echinochloa colona* and *Melilotus alba* were higher in dominancy among the weeds. *Medicago denticulata* was found significantly higher under rice-wheat cropping system (1364 and 1435/m^2) and tremendously suppressed the yield of wheat along with other weed flora followed by rice-chickpea (65.0 and 68.4/m^2). Similar trends were observed in case of *Chenopodium album, Polygonum plabeium, Echinochloa colona* and *Melilotus alba*, which were significantly higher over remaining cropping systems except rice-garden pea where *Polygonum plabeium* was at par with that of rice-wheat cropping system (136.0 and 143.0 m^2) during both the years (Table 1). This might be due to proper availability of moisture to the plants. Similar results were reported by Patil and Sheelavantar (2004) and Chiroma *et al*. (2006).

The irrigation frequency significantly influenced the weed density in *Rabi* season in 2008-09 as well as 2009-10. The *Ammannia baccifera* and *Commelina benghalensis* were found in higher density under rice-fallow, rice-wheat, rice-garden pea cropping system and showed no significant differences, but in rice-chickpea and rice-summer maize density of both the weeds was found significantly lower during *Kharif*

Table 1. Weed density (no./m^2) as influenced by rice-based cropping system during *Rabi* season

Treatment	*Chenopodium album*		*Medicago denticulata*		*Polygonum plabeium*		*Echinochloa colona*		*Melilotus alba*		Others	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Cropping system												
Rice-fallow	25.0	26.3	20.0	21.0	15.0	15.8	9.0	9.5	10.0	10.5	17.5	18.0
	(5.05)	(5.18)	(4.53)	(4.64)	(3.94)	(4.03)	(3.08)	(3.16)	(3.24)	(3.32)	(4.24)	(4.74)
Rice-wheat	52.0	54.7	1365.0	1435.3	136.0	143.0	21.0	22.1	125.0	131.4	132.5	138.9
	(7.25)	(7.43)	(36.95)	(37.89)	(11.68)	(11.98)	(4.64)	(4.75)	(11.20)	(11.49)	(11.53)	(11.81)
Rice-garden pea	60.0	63.1	65.0	68.3	89.0	93.6	3.0	3.1	20.0	21.0	27.5	28.5
	(7.78)	(7.97)	(8.09)	(8.30)	(9.46)	(9.70)	(1.87)	(1.91)	(4.53)	(4.64)	(5.29)	(5.39)
Rice-chickpea	45.0	47.3	35.0	36.8	68.0	71.5	2.0	2.1	39.0	41.0	46.5	48.5
	(6.75)	(6.92)	(5.96)	(6.11)	(8.28)	(8.49)	(1.58)	(1.61)	(6.28)	(6.44)	(6.86)	(7.00)
Rice-summer maize	10.0	10.5	25.0	26.3	10.0	10.5	10.0	10.5	2.0	2.1	9.5	9.6
	(3.24)	(3.32)	(5.05)	(5.18)	(3.24)	(3.32)	(3.24)	(3.32)	(1.58)	(1.61)	(3.16)	(3.18)
LSD(P=0.05)	0.77	3.61	NS	NS	2.22	2.28	1.40	1.43	1.64	NS	NS	NS
Irrigation frequency												
2 irrigation	55.0	57.8	68.0	71.5	92.0	96.7	18.0	18.9	20.0	21.0	27.5	28.5
	(7.45)	(7.64)	(8.28)	(8.49)	(9.62)	(9.86)	(4.30)	(4.41)	(4.53)	(4.64)	(5.29)	(5.39)
4 irrigation	42.0	44.2	55.0	57.8	62.0	65.2	9.0	9.5	(14.0	14.7	21.5	22.2
	(6.52)	(6.68)	(7.45)	(7.64)	(7.91)	(8.10)	(3.08)	(3.16)	(3.81)	(3.90)	(4.69)	(4.77)
6 irrigation	30.0	31.5	28.0	29.4	45.0	47.3	5.0	5.3	9.0	9.5	16.5	17.0
	(5.52)	(5.66)	(5.34)	(5.47)	(6.75)	(6.92)	(2.35)	(2.40)	(3.08)	(3.16)	(4.12)	(4.18)
LSD(P=0.05)	1.00	1.02	2.11	2.18	1.17	1.18	0.73	0.76	0.73	0.75	0.58	0.60

The data in parentheses were transformed with square root transformation $\sqrt{x + 0.5}$

season of 2008-09 and 2009-10, respectively (Table 1). Other weed flora also contributed significantly in density in both the years. There was no statistical difference between rice-fallow and rice-wheat cropping system in case of both the weeds, but it was lower when rice-garden pea, rice-chickpea and rice-summer maize cropping systems were taken in cultivation wherein lowest level of weeds was observed under rice-chickpea than other crops of *Rabi* season. The lower density of weeds was noticed under rice-fallow and rice-summer maize because lands were not used under continuous cultivation as rice-fallow in *Rabi* season led to lower density only on residual moisture.

The irrigation frequency for crops had drastic change in weed pattern from 2 to 6 irrigations. Under two irrigations, all weeds in *Kharif* season were noticed lower but increased significantly with four irrigation whereas under six irrigation, highest weed density was recoded which were still comparable to that of four irrigation during both the years. The higher level of irrigations had higher level of weed dominancy regardless the weed flora prevalent. The six irrigation and four irrigations were at par with each other in case of *Chenopodium album, M. denticulata, P. plabeium, E. colona* and *Melilotus alba* (Table 2).

Dry weight of weeds

In *Kharif* season, dry weight of weed was influenced significantly by cropping system and irrigation frequency because of association of weeds and availability of nutrients along with water. *Echinochloa colona* and *Cyperus iria* were identical in attaining dry weight under rice-fallow, rice-wheat and rice-chickpea cropping system, where dry weight was higher as compared to rice-garden pea and rice-summer maize cropping systems due to availability soil moisture in case of fallow and wheat. Under fallow, moisture depleted slowly because of no interfere of soil profile which promoted growth of weeds but when wheat cultivation was done by conventional tillage, although moisture was lost, yet it was compensated by frequent irrigation. On the other hand, in rice-chickpea cropping system, less disturbed and frequent irrigations also helped to retain moisture longer than other cropping to conserve seed banks for coming season (Table 3). This finding is in line with those of Ghadage *et al.* (2006). *Ammannia baccifera* and *Commelina benghalensis* were also found under similar level of suppression in all cropping systems except rice-summer maize system of cropping due to longer vacant period of moisture absence in field during winter after rice harvest. Other weeds were not affected significantly by rice-fallow and rice-wheat cropping systems. In case of irrigation frequency, two irrigations reduced the dry matter of weeds which was significantly lower than four and six irrigation. Both the irrigations equally increased the dry matter of weeds during *Kharif* 2008-09 and 2009-10, in care of *E. colona*, *Cyperus iria*, *Ammania beccifera*, *Commelina benghalensis* and even of other weeds (Table 3). Fre-

Table 2. Weed density (no./m^2) as influenced by rice-based cropping system during *Kharif* season

Treatment	*Echinochloa colona*		*Cyperus iria*		*Ammannia baccifera*		*Commelina beghalensis*		Others	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Cropping system										
Rice-fallow	30.0 (5.52)	31.3 (5.64)	25.0 (5.05)	26.1 (5.16)	10.0 (3.24)	10.4 (3.31)	6.0 (2.55)	6.3 (2.60)	10.0 (3.24)	10.4 (3.31)
Rice-wheat	28.0 (5.34)	29.3 (5.46)	18.0 (4.30)	18.8 (4.39)	9.0 (3.08)	9.4 (3.15)	5.0 (2.35)	5.2 (2.39)	8.0 (2.92)	8.4 (2.98)
Rice-garden pea	20.0 (4.53)	20.9 (4.63)	16.0 (4.06)	16.7 (4.15)	6.0 (2.55)	6.3 (2.60)	4.0 (2.12)	4.2 (2.16)	7.0 (2.74)	7.3 (2.80)
Rice-chickpea	25.0 (5.05)	26.1 (5.16)	20.0 (4.53)	20.9 (4.63)	8.0 (2.92)	8.4 (2.98)	6.0 (2.55)	6.3 (2.60)	5.0 (2.35)	5.2 (2.39)
Rice-summer maize	22.0 (4.74)	23.0 (4.85)	24.0 (4.95)	25.1 (5.06)	5.0 (2.35)	5.2 (2.39)	3.0 (1.87)	3.1 (1.91)	7.0 (2.74)	7.3 (2.80)
LSD(P=0.05)	0.61	0.53	0.75	0.77	0.69	0.33	0.43	0.21	0.32	0.33
Irrigation frequency										
2 irrigation	12.0 (3.54)	12.5 (3.61)	15.0 (3.94)	15.7 (4.02)	8.0 (2.92)	8.4 (2.98)	6.0 (2.55)	6.3 (2.60)	9.0 (3.08)	9.4 (3.15)
4 irrigation	18.0 (4.30)	18.8 (4.39)	25.0 (5.05)	26.1 (5.16)	12.0 (3.54)	12.5 (3.61)	9.0 (3.08)	9.4 (3.15)	11.0 (3.39)	11.5 (3.46)
6 irrigation	26.0 (5.15)	27.2 (5.26)	29.0 (5.43)	30.3 (5.55)	13.0 (3.67)	13.6 (3.75)	10.0 (3.24)	10.4 (3.31)	12.0 (3.54)	12.5 (3.61)
LSD(P=0.05)	0.85	0.87	0.39	0.40	0.14	0.15	0.16	0.17	0.15	0.16

The data in parentheses were transformed with square root transformation $\sqrt{x + 0.5}$

quency of irrigation increased the dry mater owing to greater availability of resources at certain intervals. Similar findings have also been reported by Chhokar *et al.* (2007).

In *Rabi* season, different weeds were observed short stature except *Echinochloa colona* and *Setria glauca* in fields. *Chenopodium album* had significantly lower dry matter (8.75g/m^2) under rice-follow and rice-summer maize cropping as compared to the rest of cropping systems where dry matter was identical in statistical scale in reducing accumulation during 2008-09 and 2009-10 (Table 4). The weeds like *M. denticulata, Polygonum plabeium, E. colona* and *M. alba* were very prominent in *Rabi* season and found

Table 3. Dry weight of weeds (g/m^2) influenced by rice-based cropping system during *Kharif* season

Treatment	*Echinochloa colona*		*Cyperus iria*		*Ammannia baccifera*		*Commelina benghalensis*		Others	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Cropping system										
Rice-fallow	10.5	11.0	8.75	9.15	3.50	3.66	2.10	2.19	3.50	3.66
	(3.32)	(3.39)	(3.04)	(3.11)	(2.00)	(2.04)	(1.61)	(1.64)	(2.00)	(2.04)
Rice-wheat	9.80	10.24	6.30	6.58	3.15	3.29	1.75	1.83	2.80	2.93
	(3.21	(3.28)	(2.61)	(2.66)	(1.91)	(1.95)	(1.50)	(1.53)	(1.82)	(1.85)
Rice-garden pea	7.00	7.32	5.60	5.85	2.10	2.19	1.40	1.46	2.45	2.56
	(2.74)	(2.80)	(2.47)	(2.52)	(1.61)	(1.64)	(1.38)	(1.40)	(1.72)	(1.75)
Rice-chickpea	8.75	9.15	7.00	7.32	2.80	2.93	2.10	2.19	1.75	1.83
	(3.04)	(3.11)	(2.74)	(2.80)	(1.82)	(1.85)	(1.61)	(1.64)	(1.50)	(1.53)
Rice-summer maize	7.70	8.05	8.40	8.78	1.75	1.83	1.05	1.10	2.45	2.56
	(2.86)	(2.92)	(2.98)	(3.05)	(1.50)	(1.53)	(1.24)	(1.26)	(1.72)	(1.75)
LSD(P=0.05)	0.35	0.36	0.38	0.46	0.43	0.40	0.24	0.37	0.23	0.22
Irrigation frequency										
2 irrigation	4.2	4.39	5.25	5.49	2.80	2.93	2.10	2.19	3.15	3.29
	(2.17)	(2.21)	(2.40)	(2.45)	(1.82)	(1.85)	(1.61)	(1.64)	(1.91)	(1.95)
4 irrigation	6.30	6.58	8.75	9.15	4.20	4.39	3.15	3.29	3.85	4.03
	(2.61)	(2.66)	(3.04)	(3.11)	(2.17)	(2.21)	(1.91)	(1.95)	(2.09)	(2.13)
6 irrigation	9.10	9.51	10.15	10.61	4.55	4.76	3.50	3.66	4.20	4.39
	(3.10)	(3.16)	(3.26)	(3.33)	(2.25)	(2.29)	(2.00)	(2.04)	(2.17)	(2.21)
LSD(P=0.05)	0.49	0.51	0.23	0.22	0.08	0.09	0.91	0.09	0.08	0.08

The data in parentheses were transformed with square root transformation $\sqrt{x + 0.5}$

Table 4. Dry weight of weeds (g/m^2) influenced by rice-based cropping system during *Rabi* season

Treatment	*Chenopodium album*		*Medicago denticulata*		*Polygonum plabeium*		*Echinochloa colona*		*Melilotus alba*	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Cropping system										
Rice fallow	8.75	9.20	7.00	7.36	5.25	5.52	3.15	3.31	3.50	3.68
	(3.04)	(3.11)	(2.74)	(2.80)	(2.40)	(2.45)	(1.91)	(1.95)	(2.00)	(2.04)
Rice - wheat	18.20	19.14	477.75	502.36	47.60	50.05	7.35	7.73	43.75	46.00
	(4.32)	(4.43)	(21.87)	(22.42)	(6.94)	(7.11)	(2.80)	(2.87)	(6.65)	(6.82)
Rice - garden pea	21.00	22.08	22.75	23.92	31.15	32.75	1.05	1.10	7.00	7.36
	(4.64)	(4.75)	(4.82)	(4.94)	(5.63)	(5.77)	(1.24)	(1.26)	(2.74)	(2.80)
Rice - chickpea	15.75	16.56	12.25	12.88	23.80	25.03	0.70	0.74	13.65	14.35
	(4.03)	(4.13)	(3.57)	(3.66)	(4.93)	(5.05)	(1.10)	(1.11)	(3.76)	(3.85)
Rice - summer maize	3.50	3.68	8.75	9.20	3.50	3.68	3.50	3.68	0.70	0.74
	(2.00)	(2.04)	(3.04)	(3.11)	(2.00)	(2.04)	(2.00)	(2.04)	(1.10)	(1.11)
LSD (P=0.05)	1.04	1.08	0.31	0.32	0.40	0.42	0.81	0.84	0.91	0.93
Irrigation frequency										
2 irrigation	19.25	20.24	23.80	25.03	32.20	33.86	6.30	6.63	7.00	7.36
	(4.44)	(4.55)	(4.93)	(5.05)	(5.72)	(5.86)	(2.61)	(2.67)	(2.74)	(2.80)
4 irrigation	14.70	15.46	19.25	20.24	21.70	22.82	3.15	3.31	4.90	5.15
	(3.90)	(3.99)	(4.44)	(4.55)	(4.71)	(4.83)	(1.91)	(1.95)	(2.32)	(2.38)
6 irrigation	10.50	11.04	9.80	10.30	15.75	16.56	1.75	1.84	3.15	3.31
	(3.32)	(3.40)	(3.21)	(3.29)	(4.03)	(4.13)	(1.50)	(1.53)	(1.91)	(1.95)
LSD (P=0.05)	0.58	0.60	1.23	1.27	0.69	0.71	1.65	0.43	1.42	0.43

The data in parentheses were transformed with square root transformation $\sqrt{x + 0.5}$

Table 5. Economics of rice-based cropping system influenced by different cropping system

Treatment	Rice equivalent yield (t/ha)		Gross return (x10^3 `/ha)		Net returns (x10^3 `/ha)		B:C ratio	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Cropping system								
Rice-fallow	3.01	3.63	30.12	32.83	25.62	27.67	2.85	2.92
Rice-wheat	5.42	11.75	54.20	59.08	47.20	50.98	4.10	4.22
Rice-garden pea	6.61	17.49	66.13	72.08	58.63	63.32	4.89	5.02
Rice-chickpea	7.20	20.76	72.04	78.52	63.43	68.50	4.84	4.97
Rice-summer maize	4.83	9.32	48.26	52.60	40.16	43.37	3.19	3.27
LSD(P=0.05)	1.78	2.01	0.18	19.45	16.23	17.53	0.76	0.81
Irrigation frequency								
2 irrigation	4.21	7.11	42.15	45.94	34.65	37.42	2.89	2.97
4 irrigation	5.02	10.10	50.25	54.77	42.26	45.64	3.38	3.48
6 irrigation	6.82	18.63	68.24	74.38	59.99	64.79	4.71	4.83
LSD(P=0.05)	1.80	8.53	0.017	19.61	17.73	19.14	1.33	1.35

to be significantly higher in accumulation of dry matter and no single cropping system was able to beat this level under rice-wheat cropping system except *E. colona* under rice-summer maize in *Rabi* season. The reverse trend was noticed in *Rabi* season as compared to *Kharif*, where less irrigation had higher dry matter of weeds and it was reduced with increasing frequency of irrigation. Therefore, six irrigation reduced drastic reduction of dry matter accumulation in *Rabi* weeds as they did not have the capacity to tolerant six frequency of irrigation. This may help to lowering weed competition in crops especially in later stage. This result indicated that incorporation of succeeding crops in *Rabi* season as in rice-fallow contributed more than alone. This might be owing to higher total productivity than rice-fallow cropping system. The above results were in conformity with the findings reported by Reddy and Suresh (2008) and Sarkar and Gangwar (1998).

Economic analysis

The highest rice equivalent yield (7.72-7.76 t/ha) under rice-chickpea cropping system was significantly superior over rest of cropping system and was at par with rice-wheat (5.42 and 5.75 t/ha) and rice-garden pea (6.61. and 6.49 t/ha) during 2008-09 and 2009-10. The gross returns were also higher in the system of cropping because of higher value of produce. The rice-chickpea cropping system fetched gross return of ` 72,040 and 78,523/ha/annum followed by rice-chickpea and rice-wheat cropping systems. The net profitability was higher in rice-chickpea cropping system due to higher gross return. Similar trend was noticed for higher B:C ratio with rice-chickpea cropping system (4.84 and 4.97). The inclusion of *Rabi* crops in fallow sequences could boost the profitability of cropping system. These results confirm the findings of Samui *et al.* (2004).

REFERENCES

Chhokar RS, Sharma RK, Jat GR, Pundir AK and Gathala MK. 2007. Effect of tillage and herbicides on weeds and productivity of wheat under rice-wheat growing systems. *Crop Protection* **26**: 1689-1696.

Chiroma AM, Alhassan and Yabuku H. 2006. Growth, nutrient composition and straw yield of sorghum as affected by land configuration and wood-chips mulch on sandy loam soil in North-East Nigeria. *International Journal of Agriculture and Biology* **8**(6): 770-775.

Ghadage HL, Kathepuri JV, Sankpal VY and Jiawale SM. 2006. Integrated weed management in winter onion (*Alliam cepa* L.) under irrigated conditions. *Research on Crops* **7**(1): 275-78.

Patil SL and Sheelavantar MN. 2004. The effect of moisture conservation increase dry matter production and its translocation to ear in winter sorghum. *Agriculture Water Management* **64**(1): 49-67.

Pradhan Adikant, Thakur A and Sonboir HL. 2014. Response of rice (*Oryza sativa* L.) varieties to different levels of nitrogen under aerobic rainfed ecosystem. *Indian Journal of Agronomy* **59**(1):50-53.

Reddy BN and Suresh G. 2008. Crop diversification with oilseeds for higher profitability, pp. 33-37. In: *Proceedings of National Symposium on "New Paradigms in Agronomic Research"* November 19-21, 2007, Navsari, Gujarat.

Samui RC, Kundu AH, Majumdar D, Mani PK and Salu PK. 2004. Diversification of rice (*Oryza sativa*)based cropping system in new alluvial zone of west Bengal. *Indian Journal of Agronomy* **49**(2): 71-73.

Sarkar A and Gangwar B. 1998. Studies on cropping system in some agro-ecosystems under irrigated conditions, pp. 121-124. In: *Proceeding of National Seminar on Water Management for Sustainable Agriculture-Problems and Perspectives for 21st Century,* Indian Agriculture Research institute, New Delhi.

Indian Journal of Weed Science **46**(3): 229–233, 2014

Effect of herbicides on soil microorganisms in direct-seeded rice

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ABSTRACT

The use of herbicides in direct-seeded rice may affect the biological equilibrium of the soil and thus influence the nutrient status, health and productivity of the soil. To study the effect of herbicides on soil microbial population of direct-seeded rice, field experiment was conducted at Punjab Agricultural University, Ludhiana (Punjab) during *Kharif* 2009 and 2010. Sixteen weed control treatments, *viz*. pendimethalin 0.75, butachlor 1.50, thiobencarb 1.50, anilofos 0.375, pretilachlor 0.75, oxadiargyl 0.09 and pyrazosulfuron-ethyl 0.015 kg/ha applied as pre-emergence and each followed by bispyribac 0.025 kg/ha at 30 days after sowing; two hand weedings and unweeded control were tested. The results revealed that viable microbial population was influenced to varying degrees with different weed control treatments during both the years. The herbicides, *viz*. pendimethalin, butachlor, thiobencarb, anilofos, pretilachlor, oxadiargyl and pyrazosulfuron-ethyl as pre-emergence and bispyribac as post-emergence were safe for soil microbial populations at recommended rate.

Key words: Actinobacteria, Bacteria, Direct-seeded rice, Fungi, Herbicides, Non-target organisms

To meet the global rice demand, it is estimated that about 114 million tonnes of additional milled rice need to be produced by 2035 which is equivalent to an overall increase of 26 per cent in the next 25 years (Kumar and Ladha 2011). To sustain present food self-sufficiency and to meet future food requirements, India has to increase its rice productivity by 3 per cent per annum but the possibility of expanding the area under rice in the near future is limited. There has, however, been stagnation in rice productivity in recent years and long-term experiments showed a declining trend in rice yield. Due to receding water table, rising costs of labour for transplanting of paddy and the adverse effects of puddling on soil health; direct-seeded rice (DSR) is gaining popularity. But, weeds are the main constraint for farmers practising direct- seeding so use of herbicides both pre- and post-emergence is required for good crop. An unintended consequence of the application of herbicides is that it may lead to significant changes in the populations of microorganisms and their activities thereby influencing the microbial ecological balance in the soil (Min *et al*. 2002, Saeki and Toyota 2004) and affecting the productivity of soils. When herbicides are applied in soil, they may exert certain side effects on non-target organisms. Therefore, there has been considerable interest on the influence of herbicides on the soil microflora and microbially mediated processes. The effects of these chemicals on certain variables are associated with microbial biomass and their activity (Wardle and Parkinson 1991). The increasing reliance of rice cultivation on herbicides has led to concern about their eco-toxicological behaviour in the rice field environment. Soil health and microbial diversity have become vital issues for the sustainable agriculture. Loss of microbial biodiversity can affect the functional stability of the soil microbial community and soil health. Generally, there are some negative effects of herbicides on the population level or composition of species. The impact of applied herbicides on the soil microbial populations were studied which included analysis of bacteria, actinobacteria and fungi counts. In Punjab, seven pre-emergence herbicides are being used in direct-seeded rice for chemical weed control, therefore, this work was carried out to estimate the counts of these microbes at different period of crop growth after their application.

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MATERIALS AND METHODS

The experiment was conducted at Students' Research Farm, Department of Agronomy, PAU, Ludhiana during *Kharif* season of 2009 and 2010. Ludhiana is situated in Trans-Gangetic Agro-Climatic zone, representing the Indo-Gangetic Alluvial plain at 30°56' N latitude, 75°52' E longitude and at an altitude of 247 m above mean sea level. The meteorological data recorded during rice growing season showed that the overall weather during 2009 remained good for the rice crop but it was not as conducive for rice during 2010. The average minimum temperature during the crop growing season of 2010 was higher by 1 °C than normal. The total rainfall of 818 and 627.6

mm were received during 2009 and 2010, respectively. The soil of the experimental site was loamy sand in texture with normal soil reaction and electrical conductivity, low in organic carbon and available N and medium in available P and K. The experiment comprised of 16 weed control treatments, *viz*. alone application of pendimethalin 0.75, butachlor 1.50, thiobencarb 1.50, anilofos 0.375, pretilachlor 0.75, oxadiargyl 0.09 and pyrazosulfuron- ethyl 0.015 kg/ha as pre-emergence and with sequential application of bispyribac 0.025 kg/ha at 30 DAS; two hand weeding and un-weeded control. The experiment was laid out in randomised complete block design with three replications. Rice variety '*PAU 201*' was seeded on 6^{th} June 2009 and 4^{th} June 2010 with tractor drawn conventional drill using primed seed after seed treatment with seed rate of 35 kg/ha in rows spaced at 20 cm. The recommended dose of fertilizers and plant protection measures for insect-pest and disease control were applied.

The composite soil samples were taken at 2 DAS (*i.e.* 0 days after spray of pre-emergence herbicides), 30 DAS (*i.e.* 0 days after spray of post-emergence herbicides and 30 days after spray of pre-emergence herbicides), 60 and 90 DAS and at harvest. Four samples of soil under each treatment were taken from 0-15 cm soil depth and mixed so as to have a representative sample of the treatment. The viable microbial counts were analyzed by the standard technique of serial dilution and pour plating. The bacterial population was estimated by growing on soil extract agar (Allen 1957) culture media composing 1.0 g glucose, 0.5 g KH_2SO_4, 0.1g KNO_3, 100 ml soil extract, 15 g agar, and 1000 ml distilled water with pH of 6.8-7.0. The population of actinobacteria was grown on dextrose nitrate agar (Küster and Williams 1964) culture media comprising 1 g dextrose, 0.1 g KH_2PO_4, 0.1 g $NaNO_3$, 0.1 g KCl, 15 g agar, and 1000 ml distilled water with pH of 7.0-7.2. The fungal population was cultured on rose bengal agar (Martin 1950) culture media having 10 g dextrose, 5 g peptone, 1 g K_2HPO_4, 0.05 g $MgSO_4.7H_20$, 0.033 g rose bengal, 15 g agar, and 1000 ml distilled water with pH of 5.5. After allowing for development of discrete bacterial colonies during incubations under suitable conditions, the colonies were counted and the number of viable bacteria, fungi and actinobacteria [expressed as colony forming units (cfu)] per gram dry weight of soil was estimated by taking into account the soil dilutions. Statistical significance of the treatment effects on different parameters was determined for the least significant difference (LSD) at 5% level of significance using analysis of variance for a randomised complete block design (Cochran and Cox 1957). Normality, homogeneity of variance, and interactions of treatments and years were tested. Interactions among years were significant; therefore, data were presented separately for each year.

RESULTS AND DISCUSSION

There was seasonal variation found in the microbial population observed at different periodical observation as most of the rainfall was received during the vegetative period. At 0 days after spray, statistically similar viable microbial counts were found in different pre-emergence herbicides and control (Table 1). At 30 days after spray, microbial count was not affected by different weed control treatments (Table 2). The herbicides and their degradation products generally take some time to accumulate in the soil and then affect the soil microflora. Actinobacteria were less affected as compared to bacteria and fungi. Actinobacteria are reported relatively resistant to herbicides and get affected at high concentration only as reported by Sondhia (2008). Raut *et al.* (1997) found that except for a slight initial suppressing effect for 0-3 days, butachlor 1.5 kg/ha stimulated the microbial activity of rice rhizosphere and increased significantly in 30 days.

The preceding trend followed when the observations on the microbial population was taken at 60 days after spray (Table 3). The microbial populations were not significantly affected by different weed control treatments. The microbial populations in the herbicide treated plots were more or less similar to the control plots (unweeded and hand weeding) thus indicating that herbicides have no detrimental effect on soil health at the applied doses. Roger (1995) also concluded that microbial activities were more sensitive to pesticides than population densities. Also, pesticide degradation in rice fields was favoured by high temperatures which usually stabilize in range favouring high microbial activity and further accelerated by organic matter incorporation. Chen *et al.* (2009) reported that microbial activity was suppressed shortly after butachlor application but was augmented after 37 days in both upper and lower soils. Min *et al.* (2001) reported that number of actinobacteria declined significantly after the application of butachlor at different concentrations ranging from 5.5 µg to 22.0 µg/g dried soil, while that of bacteria and fungi increased. Latha and Gopal (2010) reported that application of herbicides reduced the population of all the bacteria counted during the study with butachlor showing highest reduction in the populations. This effect was stronger with increasing concentration of the herbicides employed. However, the populations at field rate (FR) and also 2 FR for pyrazosulfuron-ethyl concentrations recovered within 30 days to reach populations not significantly different from the control treatments.

Table 1. Effect of weed control treatments on microbial population of soil at 2 DAS* in direct-seeded rice

Treatment	Dose (kg/ha)	Time of application	Viable counts in soil (cfu/g) 2009 Fungi ($\times10^3$)	2009 Actinobacteria ($\times10^4$)	2009 Bacteria ($\times10^6$)	2009 Soil moisture (%)	2010 Fungi ($\times10^3$)	2010 Actinobacteria ($\times10^4$)	2010 Bacteria ($\times10^6$)	2010 Soil moisture (%)
Pendimethalin	0.75	PE	23.2	16.1	20.7	14.3	17.9	19.0	16.9	12.9
Butachlor	1.50	PE	17.8	16.0	17.2	15.3	18.6	20.8	16.5	13.2
Thiobencarb	1.50	PE	22.1	16.9	18.2	18.2	18.0	21.7	14.3	15.2
Anilofos	0.375	PE	21.0	14.6	19.8	17.8	16.9	20.8	16.9	10.7
Pretilachlor	0.75	PE	24.0	14.0	20.2	12.9	18.8	19.3	15.6	11.1
Oxadiargyl	0.09	PE	17.1	14.7	17.5	14.5	18.3	20.7	14.7	12.2
Pyrazosulfuron-ethyl	0.015	PE	20.0	14.3	17.7	13.7	14.9	19.1	13.4	17.6
Unsprayed	-	-	15.5	13.9	15.8	16.1	17.2	19.7	16.6	18.8
LSD(P=0.05)			NS	NS	NS	-	NS	NS	NS	-

*2 DAS means 0 day after spray of pre-emergence herbicides, PE = Pre-emergence

Table 2. Effect of weed control treatments on microbial population of soil at 30 DAS* in direct-seeded rice

Treatment	Dose (kg/ha)	Time of application	Viable counts in soil (cfu/g) 2009 Fungi ($\times10^3$)	2009 Actinobacteria ($\times10^4$)	2009 Bacteria ($\times10^6$)	2009 Soil moisture (%)	2010 Fungi ($\times10^3$)	2010 Actinobacteria ($\times10^4$)	2010 Bacteria ($\times10^6$)	2010 Soil moisture (%)
Pendimethalin	0.75	PE	16.8	19.9	13.0	10.7	13.1	19.3	15.6	11.8
Pendimethalin *fb* bispyribac	0.75 *fb* 0.025	PE *fb* at 30 DAS	18.8	22.4	13.2	12.9	11.7	18.2	17.0	11.5
Butachlor	1.50	PE	16.8	21.8	11.2	13.4	16.1	19.0	12.8	11.7
Butachlor *fb* bispyribac	1.50 *fb* 0.025	PE *fb* at 30 DAS	19.9	21.1	14.8	12.4	14.5	21.3	12.7	11.5
Thiobencarb	1.50	PE	21.2	20.4	12.9	14.1	15.3	18.2	14.2	14.4
Thiobencarb *fb* bispyribac	1.50 *fb* 0.025	PE *fb* at 30 DAS	24.3	22.5	11.5	15.0	12.4	16.6	13.3	12.5
Anilofos	0.375	PE	20.2	18.3	12.4	13.4	11.3	18.0	13.6	12.8
Anilofos *fb* bispyribac	0.375 *fb* 0.025	*fb* at 30 DAS	19.0	20.8	14.6	16.1	15.9	21.0	13.3	15.8
Pretilachlor	0.75	PE	16.7	23.7	14.7	13.1	14.7	20.9	12.6	14.1
Pretilachlor *fb* bispyribac	0.75 *fb* 0.025	PE *fb* at 30 DAS	16.2	22.0	12.9	14.9	12.6	18.7	14.6	9.5
Oxadiargyl	0.09	PE	21.8	19.4	13.4	11.6	14.4	17.0	15.7	12.9
Oxadiargyl *fb* bispyribac	0.09 *fb* 0.025	PE *fb* at 30 DAS	21.9	22.7	13.0	14.7	13.4	21.6	12.5	17.3
Pyrazosulfuron-ethyl	0.015	PE	22.8	18.7	14.1	14.9	12.8	19.3	15.0	13.7
Pyrazosulfuron-ethyl *fb* bispyribac	0.015 *fb* 0.025	PE *fb* at 30 DAS	15.6	19.0	11.9	14.8	12.0	18.1	14.6	11.1
Two hand weeding	-	25 and 45 DAS	17.0	18.3	10.9	12.6	14.3	18.2	14.0	11.4
Unweeded	-	-	18.1	11.7	13.7	13.5	14.5	17.8	13.0	13.0
LSD(P=0.05)			NS	NS	NS	-	NS	NS	NS	-

*30 DAS *i.e.* 0 day after spray of post-emergence herbicide

The counts of fungi and actinobacteria were significantly affected by different herbicides at 90 days after spray whereas that of bacteria remained unaffected (Table 4). Among different weed control treatments, there were significantly lower counts of fungi, actinobacteria and bacteria in the unsprayed and in two hand weeding. Significantly higher microbial populations in the herbicidal treatments at all stages of observation might be due to healthy and conducive environment for the microorganisms as compared to the control. No particular pattern of the microbial counts was observed among weed control treatments but the microbial counts were significantly lower in control plots. It may be concluded that there was increase in the biological properties of the soil in well aerated aerobic soil conditions found in direct seeded rice hence might be ascribed to the improvement in the nutrient status as well as physical conditions of the soil which resulted in better growth of the microorganisms. It could be further inferred that the microbial population started to regain after the weeds were also killed by the herbicides and got mixed in the soil during this period and these might have served to increase the nutrients. The degradation of herbicides may be serving as carbon source for growth of microbes.

Table 3. Effect of weed control treatments on microbial population of soil at 60 DAS in direct-seeded rice

Treatment	Dose (kg/ha)	Time of application	Viable counts in soil (cfu/g) 2009 Fungi ($\times10^3$)	2009 Actinobacteria ($\times10^4$)	2009 Bacteria ($\times10^6$)	2009 Soil moisture (%)	2010 Fungi ($\times10^3$)	2010 Actinobacteria ($\times10^4$)	2010 Bacteria ($\times10^6$)	2010 Soil moisture (%)
Pendimethalin	0.75	PE	19.8	36.9	21.9	9.4	14.0	12.6	14.1	15.6
Pendimethalin *fb* bispyribac	0.75 *fb* 0.025	PE *fb* at 30 DAS	19.6	32.9	22.7	9.7	12.2	13.0	13.4	18.2
Butachlor	1.50	PE	20.7	33.1	17.3	8.7	13.7	12.6	14.0	18.5
Butachlor *fb* bispyribac	1.50 *fb* 0.025	PE *fb* at 30 DAS	18.5	25.1	17.1	11.9	12.5	13.7	13.0	17.0
Thiobencarb	1.50	PE	22.4	34.3	19.0	10.7	13.0	11.8	13.7	17.9
Thiobencarb *fb* bispyribac	1.50 *fb* 0.025	PE *fb* at 30 DAS	20.5	33.1	21.2	10.7	10.1	11.6	13.7	16.8
Anilofos	0.375	PE	17.0	29.1	20.4	12.2	12.3	11.4	13.9	17.8
Anilofos *fb* bispyribac	0.375 *fb* 0.025	PE *fb* at 30 DAS	19.2	42.0	21.5	14.6	13.6	13.9	14.2	17.7
Pretilachlor	0.75	PE	21.6	30.2	16.9	30.0	12.8	11.5	13.3	18.9
Pretilachlor *fb* bispyribac	0.75 *fb* 0.025	*PE fb* at 30 DAS	20.9	30.4	16.2	10.6	12.3	11.0	13.8	17.5
Oxadiargyl	0.09	PE	21.7	36.1	18.3	14.8	10.6	11.5	14.4	17.4
Oxadiargyl *fb* bispyribac	0.09 *fb* 0.025	PE *fb* at 30 DAS	21.8	36.5	16.8	9.8	12.6	12.2	13.8	17.8
Pyrazosulfuron-ethyl	0.015	PE	18.3	30.8	16.9	10.8	11.6	11.6	15.3	18.7
Pyrazosulfuron-ethyl *fb* bispyribac	0.015 *fb* 0.025	PE *fb* at 30 DAS	17.9	28.5	19.9	11.2	11.4	10.7	13.3	19.7
Two hand weeding	-	25 and 45 DAS	19.1	32.6	19.7	11.6	11.5	10.9	15.0	18.2
Unweeded	-	-	17.8	30.2	16.2	12.6	11.5	9.7	13.4	16.1
LSD(P=0.05)			NS	NS	NS	-	NS	NS	NS	-

Table 4. Effect of weed control treatments on microbial population of soil at 90 DAS in direct-seeded rice

Treatment	Dose (kg/ha)	Time of application	Viable counts in soil (cfu/g) 2009 Fungi ($\times10^3$)	2009 Actinobacteria ($\times10^4$)	2009 Bacteria ($\times10^6$)	2009 Soil moisture (%)	2010 Fungi ($\times10^3$)	2010 Actinobacteria ($\times10^4$)	2010 Bacteria ($\times10^6$)	2010 Soil moisture (%)
Pendimethalin	0.75	PE	23.4	40.5	12.4	8.1	29.0	15.0	13.9	18.9
Pendimethalin *fb* bispyribac	0.75 *fb*0.025	PE *fb* at 30 DAS	23.8	38.2	12.7	11.9	26.1	14.3	14.8	17.2
Butachlor	1.50	PE	21.7	37.2	13.8	20.1	26.7	13.1	13.8	18.0
Butachlor *fb* bispyribac	1.50 *fb* 0.025	PE*fb*at 30 DAS	23.3	39.4	12.9	10.6	27.3	15.2	14.1	18.7
Thiobencarb	1.50	PE	22.8	35.3	13.6	13.7	27.4	13.3	13.3	17.4
Thiobencarb *fb* bispyribac	1.50 *fb* 0.025	PE*fb* at 30 DAS	23.5	33.5	9.8	12.6	28.8	13.7	13.4	17.7
Anilofos	0.375	PE	20.4	34.0	11.8	12.1	29.5	13.5	15.3	17.3
Anilofos *fb* bispyribac	0.375 *fb* 0.025	PE*fb* at 30 DAS	24.7	35.4	11.8	12.5	26.7	13.8	14.4	16.2
Pretilachlor	0.75	PE	21.4	39.6	12.4	16.9	27.3	15.6	11.1	17.6
Pretilachlor *fb* bispyribac	0.75*fb* 0.025	PE*fb* at 30 DAS	20.1	34.0	12.2	12.8	27.3	13.5	13.9	16.2
Oxadiargyl	0.09	PE	21.1	35.6	13.1	8.5	29.4	14.8	12.6	18.5
Oxadiargyl *fb* bispyribac	0.09 *fb* 0.025	PE*fb*at 30 DAS	23.6	35.9	13.3	13.5	29.1	13.2	13.1	14.3
Pyrazosulfuron ethyl	0.015	PE	19.7	33.6	12.8	14.4	27.8	14.6	11.1	15.2
Pyrazosulfuron ethyl *fb* bispyribac	0.015 *fb* 0.025	PE *fb*at 30 DAS	22.9	36.2	12.1	14.6	26.6	15.4	12.2	18.7
Two hand weedings	-	25 and 45 DAS	11.4	20.8	12.4	11.9	13.9	10.2	13.3	17.5
Unweeded	-	-	11.2	19.4	11.8	16.6	13.1	9.3	14.3	16.3
LSD(P=0.05)			5.1	7.7	NS	-	6.0	2.9	NS	-

The viable microbial counts were found to be statistically similar under the influence of different weed control treatments at harvest (Table 5). The monitoring period is a most important part for the assessment of pesticide effects and a minimum of 30 days has been recommended for the recognition of persistent effects on soils. A delay of 30 days in the restitution of normality (recovery period) after herbicide application should be considered normal with ecological consequences being negligible, a delay of 60 days is not

Table 5. Effect of weed control treatments on microbial population of soil at harvest in direct-seeded rice

Treatment	Dose (kg/ha)	Time of application	Viable counts in soil (cfu/g) 2009				Viable counts in soil (cfu/g) 2010			
			Fungi ($\times 10^3$)	Actinobacteria ($\times 10^4$)	Bacteria ($\times 10^6$)	Soil moisture (%)	Fungi ($\times 10^3$)	Actinobacteria ($\times 10^4$)	Bacteria ($\times 10^6$)	Soil moisture (%)
Pendimethalin	0.75	PE	12.0	16.7	11.8	9.7	13.8	14.5	11.5	12.6
Pendimethalin *fb* bispyribac	0.75 *fb*0.025	PE *fb* at 30 DAS	11.6	14.7	12.9	13.5	13.1	11.5	12.1	9.8
Butachlor	1.50	PE	11.1	14.1	13.0	15.1	10.2	11.6	12.3	14.0
Butachlor *fb* bispyribac	1.50 *fb* 0.025	PE *fb* at 30 DAS	13.0	18.0	12.2	14.9	13.1	11.3	12.4	11.2
Thiobencarb	1.50	PE	10.6	16.2	12.7	12.7	10.5	10.9	13.2	9.4
Thiobencarb *fb* bispyribac	1.50 *fb* 0.025	Pefb at 30 DAS	11.3	15.9	11.5	12.1	11.2	12.1	12.1	7.9
Anilofos	0.375	PE	9.1	14.3	13.0	10.9	11.2	14.1	10.5	10.7
Anilofos *fb* bispyribac	0.375 *fb* 0.025	PE *fb* at 30 DAS	9.2	13.5	13.5	12.3	12.2	10.4	11.3	7.1
Pretilachlor	0.75	PE	11.2	13.8	11.2	13.4	12.7	10.5	11.6	12.2
Pretilachlor *fb* bispyribac	0.75 *fb* 0.025	PE *fb* at 30 DAS	9.9	11.7	11.9	11.7	11.4	10.9	12.4	10.2
Oxadiargyl	0.09	PE	12.1	12.2	11.2	10.1	12.2	11.0	13.1	7.9
Oxadiargyl *fb* bispyribac	0.09 *fb* 0.025	PE *fb* at 30 DAS	10.2	12.9	13.4	11.6	12.3	13.4	11.3	11.2
Pyrazosulfuron-ethyl	0.015	PE	14.5	13.9	11.6	9.1	11.8	12.3	11.5	10.9
Pyrazosulfuron-ethyl *fb* bispyribac	0.015 *fb* 0.025	PE *fb* at 30 DAS	11.2	10.2	11.2	13.3	12.5	10.3	12.3	10.8
Two hand weeding-	-	25 and 45 DAS	10.6	13.8	12.4	9.6	12.8	14.7	12.9	10.3
Unweeded	-	-	9.7	14.9	12.3	10.4	11.6	10.6	12.9	10.9
LSD(P=0.05)			NS	NS	NS	-	NS	NS	NS	-

unusual, and the ecological consequences are tolerable and a delay of greater than 60 days is unusual with ecological consequences which may eventually be critical (Domsch *et al.* 1983).

The microbial populations in the herbicide treated plots were more or less similar to the unsprayed control plots thus indicating that herbicides have no detrimental effect on soil health at the applied doses.

REFERENCES

Allen ON. 1957. *Experiments in Soil Bacteriology*. Burgess Publishing Co., USA: 117 p.

Chen WC, Yen JH, Chang CS and Wang YS. 2009. Effects of herbicide butachlor on soil microorganisms and on nitrogen-fixing abilities in paddy soil. *Ecotoxicology and Environmental Safety* **72:** 120-127.

Cochran WG, Cox GM. 1992. *Experimental Designs*. 2nd Edition. John Wiley and Sons Inc., New York: 640 p.

Domsch KH, Jagnow G and Anderson KH. 1983. An ecological concept for the assessment of side effects of agrochemicals on soil microflora. *Residue Reviews* **86**: 65-105.

Kumar V and Ladha JK. 2011. Direct-seeding of rice: recent developments and future research needs. *Advances in Agronomy* **111**: 297-413.

Küster E and Williams ST. 1964. Selection of media for isolation of *Streptomycetes*. *Nature* **202**: 928-929.

Latha PC and Gopal H. 2010. Effect of herbicides on soil microorganisms. *Indian Journal of Weed Science* 42 (3&4): 217-222.

Martin JP. 1950. Use of acid, rose Bengal, and streptomycin in the plate method for estimating soil fungi. *Soil Science* **69**(3): 215-232.

Min H, Ye YF, Chen ZY, Wu WX and Yufeng D. 2001. Effects of butachlor on microbial populations and enzyme activities in paddy soil. *Journal of Environmental Science and Health* **36**(5): 581-95.

Min H, Ye YF, Chen ZY, Wu WX and Du YF. 2002. Effects of butachlor on microbial enzyme activities in paddy soil. *Journal of Environmental Sciences* 14(3): 413-417.

Raut AK, Kulshrestha G and Chhonkar PK. 1997. Effect of butachlor on microbial soil populations in rice fields. *Toxicology & Environmental Chemistry* **59:** 145-149.

Roger PA. 1995. The impact of pesticides on ricefield microflora: an analytical review of the literature, pp.271-308. In: *Impact of Pesticides on Farmer Health and the Rice Environment.* (Eds: Pingali LP, Roger PA), Book Series, National Resource Management and Policy, Vol **7.**

Saeki M and Toyota K. 2004. Effect of bensulfuron-methyl (a sulfonyurea herbicide) on the soil bacterial community of a paddy soil microcosm. *Biological Fertility Soils* **40**: 110-118.

Sondhia S. 2008. Herbicide residue in soil, water and food chain: An Indian Perspective. p. 31. In: *Proceeding of Biennial Conference, Indian Society of Weed Science*, on February 27-28, 2008, RAU, Pusa, India.

Wardle DA and Parkinson D. 1991. Relative importance of the effect of 2, 4-D, glyphosate, and environmental variables on the soil microbial biomass. *Plant and Soil* **134**: 209-219.

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Increase of wheat yield in rice-wheat system by weed management

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ABSTRACT

Sulfosulfuron at 33.3 g/ha recorded significantly lower weed intensity and biomass, higher weed control efficiency, which was at par with hand weeding 30 DAS and superior to isoproturon and 2,4 D sodium salt. The maximum nutrient removal by wheat crop and response over weedy check towards grain yield of wheat (129.6%) were with weed free treatment followed by sulfosulfuron at 33.3 g/ha and minimum in 2,4-D of sodium salt at 0.80 kg/ha. The maximum net return and B: C ratio by wheat cultivation (` 31,475/ ha and 1:1.80) was obtained with sulfosulfuron at 33.3 g/ha at par with weed free and weeding at 30 DAS than others treatments.

Key words: 2,4-D, Isoproturon**,** Sodium salt, Sulfosulfuron, Weed intensity

Rice-wheat is one of the most predominant cropping systems occupying 10.5 m ha area, especially in North India. Weed infestation in wheat is more serious problem under this system. Crop weed competition during the crop growth results 20 to 95% reduction in grain yield, which also depends on the weed intensity and type of weed flora (Kumar *et al.* 1998). The broad leaved weeds, *viz. Cannabis* spp. and *Chenopodium* spp. were found as major weeds in eastern part of Bihar. Manual weeding is expensive, energy and time consuming as well as difficult in early stage of crop growth. Herbicides were found effective against control of large number of weeds which increased the crop yield. For efficient and economic management of weeds in wheat, isoproturon and 2,4-D has been found to be the most suitable herbicides for last two decades in India (Singh *et al.* 2001). But continuous use of single herbicide may cause shifting in weed flora or resistance problems. So, keeping these facts in view, the present study was undertaken to study the effect of different herbicides on weeds and economics of wheat.

MATERIALS AND METHODS

A field experiment was conducted during two consecutive *Rabi* seasons of 2011-12 and 2012-13 at Research Farm of Bhola Paswan Shastri Agricultural College Purnea, Bihar Agricultural University, (Sabour) Bhagalpur, Bihar. The land was situated at 25^0 482 N latitude and 87^0 302 E longitude and an altitude of 102 metres above MSL in inceptisole. The soil of experimental site was sandy loam in texture, neutral in pH (6.7), low in organic carbon (0.44%) and available nitrogen (180kg /ha), medium in phosphorus (30 kg/ha), medium in available K (275 kg/ ha), medium in available S (19.1 kg/ ha), medium in available Mn (6.8 ppm), low in available Zn (0.2 ppm), high in available Fe (114.4 ppm), medium in available Cu (2.6ppm) and low in available B (0.1 ppm) status. Six treatment comprising weedy check, weed free, one hand weeding (30 DAS), isoproturon at 0.75 kg/ ha (pre-emergence), sulfosulfuron at 33.3 g/ha (post-emergence), 2,4-D sodium salt at 0.80 kg/ha (post-emergence) were laid out in randomized block design (RBD) having four replications. The recommended dose of fertilizers 100: 50: 25 kg NPK /ha were applied by urea, DAP and murate of potash. The full dose of phosphorus, potash and half dose of nitrogen was applied as basal. Remaining N was applied in two equal splits *i.e.* at tillering and booting stages. Irrigation was applied at critical stage of wheat production. Wheat variety '*HD 2985'* was sown on Nov 28, 2011 and Nov 30, 2012 using 100 kg/ha seed rate with 23 cm of row spacing apart. The experiment was conducted in fixed plots without disturbing the layout. The weed density (species wise) and dry weight were measured in each plots from randomly selected places (1.0 m^2) at 50 DAS and 80 DAS.

Weed control efficiency (WCE) was calculated on the basis of dry weight by the commonly used method and forumula.

The grain, straw and weed samples were collected and dried in oven at 65 ± 5 ^{0}C. Thereafter, these were ground, digested and analysed nitrogen by Kjeldhal method with titration of absorbed ammonia by sulphuric acid. Phosphorus content was estimated by yellow colour developed by Vandomolybedate and read-

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ing by spectrophotometer and potassium concentration was estimated by flame photometer. The percentage of nutrient content was multiplied with biomass of weed or crop yield for calculating of nutrient uptake. The cost of cultivation was calculated by taking in to account of prevailing price of inputs.

RESULTS AND DISCUSSION

The major weed flora found in experimental plots were: *Phalaris minor Retz.* in grassy weeds with *Cannabis sativa* L. , *Chenopodium album* L. and *Fumaria parviflora* L. among broad-leaved weeds. The other minor weeds were *Anagallis arvensis* L. and *Solanum nigrum* L. *etc.*

The maximum reduction in weeds was recorded with weed free treatment and minimum in weedy check (Table 1). Among different herbicides, sulfosulfuron at 33.3 g/ha significantly reduced number of weeds and weed biomass (111.3 weeds/m^2 and 58.5 g/m^2) as compared to isoproturon and 2,4-D sodium salt. However, this treatment was statistically at par with hand weeding 30 DAS. This may due to broad spectrum action of sulfosulfuron on both grassy and broad-leaved weeds (Singh *et al.* 1997, Walia *et al.* 2000, Tiwari and Vaishya 2004). The maximum weed control efficiency was found in weed free treatment which was at par with sulfosulfuron at 33.3 kg/ha and minimum in control plots.

Cannabis sativa L., *Chenopodium album* L. and *Fumaria parviflora* L. were major weeds which reduced yield of wheat in this area. Weed free followed by sulfosufuron at 33.3 g/ha as post-emergence at 30 DAS caused maximum reduction per cent of these weed species. Sulfosulfuron at 33.3 g/ha found significantly superior in controlling major weeds than isoproturon at 0.75 kg/ha at pre-emergence and 2,4-D of sodium salt at 0.80 kg/ha as post- emergence. The highest nutrient uptake (N, P and K; 36.8, 20.5 and 35.4 kg/ha, respectively) by weeds was noticed in weedy check, which was harmful for wheat crops during cultivation and indicated very high competition between crop and weeds for nutrients. Among different herbicides, sulfosulfuron treatment recorded significantly lower nutrient removal (N, P and K 10.7, 5.1 and 10.5 kg/ha, respectively) by weeds and it was found statistically similar with hand weeding at 30 DAS and superior to other chemical used in the experiments. Kumar *et al.* (1998) and Yadav *et al.* (1986) also found the similar results.

All the weed control measures significantly increased grain and straw yield over weedy check (Table 2). The weed free treatment obtained grain yield at par with sulfosulfuron and hand weeding at 30 DAS. Among different herbicides, sulfosulfuron at 33.3 g/ha recorded significantly higher grain yield (2.75 t/ha) than isoproturon and 2,4-D sodium salts. Kushwaha and Singh (2000) and Walia *et al.* (2000) also found the maximum grain yield of wheat with two hand weeding. The yield attributing characters (length of spikelet, no. of spikelet's/spike, no. of grain/spike and 1000 grain wt) of wheat followed the similar trends to grain yield. The maximum response of grain yield of wheat (129.6%) was obtained with weed free treatment followed by sulfosulfuron at 33.3 g/ha as post-emergence at 30 DAS and minimum in 2,4-D sodium salt at 0.80 kg/ha as post-emergence treatment. The maximum macronutrient (N, P and K uptake) by wheat (55.5, 11.1 and 47.0 kg/ha, respectively) were obtained with weed free and it was found at par with sulfosulfuron 33.3 g/ha at post-emergence 30 DAS and one hand weeding at 30 DAS than others treatments. The maximum net return and B:C ratio by wheat

Table 1. Effect of weed management on weed growth and nutrient removal by weeds (mean of two years)

Treatment	No of weeds/ m^2	Weeds dry weight (g/m^2)	Weed control efficiency (%)	Weed species (% decrease)				Nutrient uptake by weeds (kg/ha)		
				Cannabis sativa	*Chenopodium album*	*Fumaria parviflora*	Others	N	P	K
One HW at 30 DAS	118.8	59.5	68.5	84.0	86.0	69.0	80.0	10.2	5.6	11.0
Isoproturon 0.75 kg/ha as PE	150.0	80.8	57.2	77.0	69.0	69.0	71.0	15.1	7.3	14.9
Sulfosulfuron 33.3 g/ha as POE at 30 DAS	111.3	58.5	69.0	81.4	81.7	76.4	70.0	10.7	5.1	10.5
2,4-D sodium salt 0.80 kg/ha as POE at 30 DAS	181.3	97.8	48.2	63.0	68.0	68.0	65.0	18.1	9.1	17.9
Weedy check	390.0	188.8	0.0	-	-	-	-	36.8	20.5	35.4
Weed free	0.0	0.0	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0
LSD (P=0.05)	28.5	14.6	3.7	-	-	-	-	3.1	1.6	2.9

DAS = Days after sowing, HW = Hand weeding, PE = Pre-emergence, POE = Post-emergence

Table 2. Effect of weed management on yield, nutrient uptake and economics of wheat (mean of two years)

Treatment	Effective tiller /m²	Plant height at maturity (cm)	No of spiklets/ spike	No of grain /spike	1000 grain wt (g)	Grain yield (t/ha)	Response over weedy check	Nutrient Uptake by crop (kg/ha)			Economics	
								N	P	K	Net returns (x10³ `/ha)	B:C ratio
One HW at 30 DAS	25.9	91.8	16.1	29.4	42.3	2.59	107.2	50.0	10.2	44.3	28.73	1.64
Isoproturon 0.70 kg/ha as PE	24.1	90.8	15.3	30.2	41.9	2.41	92.8	46.9	9.8	43.5	26.59	1.58
Sulfosulfuron 33.3 g/ha as POE at 30 DAS	27.2	95.0	16.1	30.5	42.9	2.75	117.6	52.5	10.9	47.2	31.47	1.80
2,4-D sodium salt 0.80 kg/ha as POE at 30 DAS	22.8	90.5	15.1	30.6	41.2	2.28	82.4	44.3	9.4	41.2	24.28	1.44
Weedy check	12.5	77.6	9.6	21.4	37.1	1.25	-	24.1	4.8	20.1	6.15	0.37
Weed free	28.7	99.3	16.2	30.8	43.3	2.87	129.6	55.2	11.1	47.0	30.65	1.49
LSD (P=0.05)	3.3	10.4	2.3	4.0	3.5	0.31	-	6.1	1.3	6.5	5.82	0.33

DAS = Days after sowing, HW = Hand weeding, PE = Pre-emergence, POE = Post-emergence

cultivation (` 31,475/ha and 1:1.80) was obtained with sulfosulfuron 33.3 g/ha but at par with weed free and one hand weeding at 30 DAS. The minimum net return and B:C ratio was obtained with 2,4-D sodium salt.

REFERENCES

Kumar S, Singh G and Singh P. 1998. Bio-efficacy of isoproturon formulation in wheat and their effect on nutrient uptake. *Annals of Plant Protection Science* **6 (2)**: 174-177.

Kushwaha BL and Singh PK. 2000. Comparative efficacy and economics of mechanical and chemical weed control in wheat. *Annals of Plant Production Science* **8(1)**: 71-75.

Singh S, Singh AN and Bhan VM.1997. Studies on chemical weed control in wheat. *Indian Journal of Weed Science* **29**: 100-102.

Tiwari NK and Vaishya RD.2004. Effect of herbicide on weeds in late sown wheat. *Indian Journal of Weed Science* **36** (1&2): 115-116.

Walia US, Brar LS and Mehra SP. 2000. Interaction effect of nitrogen levels and weed control measures in wheat. *Indian Journal of Weed Science* **23**(1&2): 28-33.

Yadav SK, Kumar A and Bhan VM. 1986. Nutrient uptake in wheat as influenced by herbicides. *Indian Journal of Weed Science* **18**: 60-62.

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Little seed canary grass resistance to clodinafop in Punjab: farmers' perspective

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ABSTRACT

Little seed canary grass (*Phalaris minor* Retz.) is the dominant grass weed of wheat especially in rice-wheat cropping system in the North-Western Indo-Gangetic Plains of India. It developed resistance to isoproturon herbicide in early 1990's. Alternate herbicides, *viz.* clodinafop, sulfosulfuron and fenoxaprop were recommended for its control and were widely adopted by the farmers. Complaints of poor efficacy of these alternate herbicides started appearing at farmers' field, after decades of their use. Performance of these alternate herbicides was assessed, to study the occurrence of cross resistance in *P. minor*, through farmers' field survey. The survey was conducted in 2011 at 73 farmers' field in six districts *viz*. Patiala, Fatehgarh Sahib, Ludhiana, Moga, Jalandhar and Ropar in Punjab. The survey indicated that clodinafop and sulfosulfuron are widely used by the farmers. The farmers used to apply field rates of these herbicides till 2008-09 and were getting effective control of *P. minor* (>85%). During 2009-10, clodinafop started showing signs of reduced efficacy and >30% farmers used 1.5 times of field dose and control was still poor (<65%); few farmers (<10%) used 2 times the field dose with little success. In 2010-11, the farmers (<50%) used 2 times and <30% used 3 times or higher dose of clodinafop alone/tank mix of clodinafop + sulfosulfuron/both herbicides in sequence and control was still poor (0- <60%); re-growth recorded in Patiala, Fatehgarh Sahib, Ludhiana and Moga districts. Sulfosulfuron efficacy also showed declining trend (<60%) during 2010-11. Reduced efficacy of sulfosulfuron was more prevalent in fields having history of continuous use of sulfosulfuron but poor efficacy of clodinafop was even recorded in fields having continuous use of sulfosulfuron. The spray methodology adopted by the farmers was better than they were using in the previous years, hence cannot be related to the reduced herbicide efficacy. The survey results pointed towards the development of cross resistance in *P. minor* to clodinafop and indicated that sulfosulfuron was likely to meet the same fate in the near future. Proper and regular monitoring of all the existing herbicides is desirable before the situation comes out of control at farmers' field.

Key words: Clodinafop, Cross resistance, Farmer field, Sulfosulfuron

Rice-wheat is the dominant cropping system in the North-Western Indo-Gangetic Plains of India. *Phalaris minor* is the dominant grassy weed of wheat, particularly in this cropping system. It evolved resistance to isoproturon in Haryana, Punjab and Uttar Pradesh in the early 1990s (Malik and Singh 1993, Walia *et al.* 1997). On an average, a loss of 25 to 50 % in wheat yield was quite common. By 1999, it was estimated that herbicide-resistant biotypes had infested around 1 million ha area in these three states (Yaduraju 1999). The resistant biotypes have been reported to require 2- 8 times more isoproturon than susceptible ones for same level of control (Malik and Singh 1995, Walia *et al.* 1997). Alternate herbicides *viz*. clodinafop, sulfosulfuron and fenoxaprop were then recommended for the control of resistant *P. minor*. These alternate herbicides brought *P. minor* infestation under control and widely adopted in the resistant affected areas. However, the complaints of poor field efficacy of these herbicides have been reported from farmers' field during last four- five years. Looking into the present scenario, it seems that in near future, the problem of herbicide resistance in this weed may again pose a serious threat to the sustainability of wheat productivity. The field efficacy of these herbicides at farmers' field was assessed through field survey to study the occurrence of cross resistance, if any, in *P. minor* against these herbicides.

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MATERIALS AND METHODS

A survey proforma was prepared for studying the herbicide use pattern and efficacy against *P. minor* over the years. The survey was conducted during February 2011 in six districts, *viz*. Patiala, Fatehgarh Sahib, Ludhiana, Moga, Jalandhar and

Roopnagar. The first four districts have dominant rice-wheat system having medium to heavy textured soils while in Jalandhar and Roopnagar districts, many farmers practiced maize-wheat and maize-potato-wheat rotations also. Farmers were interviewed about dose, time and method of application and efficacy of different herbicides being used by them over the years. In all, 73 farmers were interviewed in all the six districts in Punjab. The selected farmers have reported problem with control of *P. minor*. The team visited majority of the farmers' field and held discussions with farmers and made on the spot assessments regarding the efficacy of the herbicides against *P. minor*.

RESULTS AND DISCUSSION

The survey indicated that clodinafop and sulfosulfuron are widely used by the farmers for control of *P. minor,* clodinafop being safe for succeeding crops was preferred over sulfosulfuron. During 2008-09, all the surveyed farmers used recommended doses of clodinafop and sulfosulfuron and got effective control (>85%) of *P. minor* (Tables 1-6). The herbicide use pattern indicated that in Patiala and Moga districts, 50-62% farmers used clodinafop and 38-43% used sulfosulfuron while in Fatehgarh Sahib, Ludhiana, Jalandhar and Roopnagar districts, 81-100 % farmers used clodinafop and 8-25% used sulfosulfuron. During 2009-10, clodinafop started showing signs of reduced efficacy and >30% farmers used 1.5 times of field dose and control was still poor (<65%); few farmers (<10%) used 2 times the field dose with little success. In Moga and Patiala districts, 9- 28% farmers used 1.5 to 2.0 times doses of clodinafop and 26% in Moga district used tank mixtures of clodinafop and sulfosulfuron at their field doses and also mixed metribuzin and still recorded poor control (<65%) of *P. minor* (Table 2 and 4). The farmers in Fatehgarh Sahib, Ludhaina, Jalandhar and Roopnagar districts used field doses of both the herbicides, however, the efficacy of clodinafop reduced from 85 to 65% which was below satisfaction; sulfosulfuron performance also declined as compared to previous year (Tables 1, 3, 5 and 6). The situation became alarming in 2010-11 when clodinafop at field dose did not show any affect against

Table 1. Herbicide use pattern and efficacy against *P. minor* in Patiala district

Herbicide	Dose (g/ha)	2008-09		2009-10		2010-11	
		% farmers	% control	% farmers	% control	% farmers	% control
Clodinafop	60	50	90.1	50	64.1	7	25.2
Clodinafop	90	0		21	60.6	7	50.5
Clodinafop	120	0		7	60.2	14	37.5
Clodinafop *fb* clodinafop	60 and 60	0		0		14	60.5
Clodinafop *fb* clodinafop	120 and 120	0		0		7	30.0
Clodinafop *fb* clodinafop + sulfosulfuron	60 and 60 + 25	0		0		14	50.5
Clodinafop *fb* clodinafop + metribuzin	120 *fb* 120 + 50	0		0		14	30.0
Fenoxaprop	100	7	90.0	0		0	
Sulfosulfuron	25	43	85.0	21	66.3	0	
Sulfosulfuron + clodinafop *fb* clodinafop	25 +60 *fb* 120	0		0		14	25.0
Sulfosulfuron *fb* sulfrosulfruon	37.5 *fb* 37.5	0		0		7	65

Table 2. Herbicide use pattern and efficacy against *P. minor* in Fatehgarh Sahib district

Herbicide	Dose (g/ha)	2008-09		2009-10		2010-11	
		% farmers	% control	% farmers	% control	% farmers	% control
Clodinafop	60	81	85.0	45	65.0	9	30.0
Clodinafop	90	0		9	70.0	0	
Clodinafop	120	0		9	60.0	18	42.0
Clodinafop *fb* clodinafop	60 and 60	0		0		9	25.0
Clodinafop *fb* clodinafop	60 and 120	0		0		9	0
Clodinafop *fb* clodinafop + sulfosulfuron	120 *fb* 120 + 25	0		0		18	15.0
Clodinafop *fb* sulfosulfuron	120 *fb* 25	0		9	60.0	9	65.0
Sulfosulfuron	25	19	80.0	27	75.0	9	85.0
Sulfosulfuron *fb* clodinafop	*25fb* 60	0		0		18	40.0

No. of farmers:11

Table 3. Herbicide use pattern and efficacy against *P. minor* in Ludhiana district

Herbicide	Dose (g/ha)	2008-09		2009-10		2010-11	
		% farmers	% control	% farmers	% control	% farmers	% control
Clodinafop	60	92	85.0	77	65.2	0	
Clodinafop	90	0		0		0	
Clodinafop	120	0		0		23	55.0
Clodinafop *fb* clodinafop	90 and 90	0		0		15	30.0
Clodinafop *fb* clodinafop	120 *fb* 120	0		0		15	40.0
Clodinafop *fb* clodinafop	120 *fb* 60	0		0		8	0
Clodinafop *fb* sulfosulfuron	120 *fb* 37.5	0		0		8	75.0
Sulfosulfuron	25	8	83.6	23	85.2	8	70.0
Sulfosulfuron + clodinafop	25+ 60	0		0		23	75.0

No. of farmers:13

Table 4. Herbicide use pattern and efficacy against *P. minor* in Moga district

Herbicide	Dose (g/ha)	2008-09		2009-10		2010-11	
		% farmers	% control	% farmers	% control	% farmers	% control
Clodinafop	60	62	85.5	33	60.2	0	
Clodinafop	90	0		9	60.0	9	40.0
Clodinafop	120	0		0		14	45.0
Clodinafop *fb* clodinafop	120 and 90	0		0		9	20.0
Clodinafop + sulfosulfuron + metribuzin	120 + 25 + 50	0		5	45.0	0	
Clodinafop *fb* clodinafop + metribuzin	120 *fb* 60 + 75	0		0		5	30.0
Clodinafop *fb* sulfosulfuron	60 *fb* 25	0		0		21	30.0
Sulfosulfuron	25	38	75.0	33	62.2	14	25.0
Sulfosulfuron *fb* clodinafop	*25 fb* 60	0		0		0	
Clodinafop + sulfosulfuron	60 + 25	0		21	65.0	14	40.5
Clodinafop *fb* sulfosulfuron + clodinafop	90 *fb* 25 + 120	0		0		9	35.0
Sulfosulfuron *fb* clodinafop *fb* clodinafop	25 *fb* 60 *fb* 120	0		0		9	30.0

No. of farmers:21

Table 5. Herbicide use pattern and efficacy against *P. minor* in Jalandhar district

Herbicide	Dose (g/ha)	2008-09		2009-10		2010-11	
		% farmers	% control	% farmers	% control	% farmers	% control
Clodinafop	60	100	85.0	100	60.5	80	50.2
Clodinafop	90	0		0		0	
Clodinafop	120	0		0		20	10.0

No. of farmers:5

P. minor and the farmers (<50%) used 2 times and <30% used 3 times or higher dose of clodinafop alone/ tank mix of clodinafop + sulfosulfuron/both herbicides in sequence and control was still poor (0- <60%); re-growth was recorded in fields particularly in Patiala, Fatehgarh Sahib, Ludhiana and Moga districts. Few farmers (<8%) used higher (1.5 times) dose of sulfosulfuron in Patiala and Moga districts only. Sulfosulfuron efficacy also showed declining trend (<60%) during 2010-11; reduced efficacy was more prevalent in fields having history of continuous use of sulfosulfuron but poor efficacy of clodinafop was even recorded in field having continuous use of sulfosulfuron. The spray technology adopted by the farmers was better than in previous years; from 2008-09 to 2010-11, the farmers have increased the volume of water used for spray and also more farmers apply the herbicides within normal period of 30- 40 days of wheat sowing as compared to previous years (Tables 7 and 8). It indicated that farmers are aware and following appropriate herbicide application technology, hence cannot be related to the reduced herbicide efficacy. The survey results pointed towards the evolution of cross resistance in *P. minor* to clodinafop. Poor efficacy of sulfosulfuron in Moga district, where farmers had history of sulfosulfuron use, indicated that even sulfosulfuron is prone to reduced efficacy with continuous use, as observed for clodinafop, and was likely to meet the same fate in the near future.

Table 6. Herbicide use pattern and efficacy against *P. minor* in Roopnagar district

Herbicide	Dose (g/ha)	2008-09		2009-10		2010-11	
		% farmers	% control	% farmers	% control	% farmers	% control
Clodinafop	60	75	85.0	62	85.0	25	70.0
Sulfosulfuron	24	25	85.0	25	75.0	12	60.0
Clodinafop + isoproturon	60 + 1000	0		12	75.0	37	75.0
Clodinafop	90	0		0		25	70.0

No. of farmers: 8

Patiala, Ludhian, Moga and Fatehgarh Sahib are typically rice-wheat cropping areas where *P. minor* is a major weed in wheat and farmers use herbicides every year to control this weed. In Jalandhar and Roopnagar areas, many farmers grow maize and potato crops in rotation with wheat. In maize and potato, weeds are controlled by triazine herbicides which effectively controlled all the winter season weed. The farmers, in general, do not spray any herbicide when wheat follows potato, hence in these districts the rotation of crops and herbicides keeps the *P. minor* under check and existing herbicides are still working well. In rice-wheat cropping areas, *P. minor* germinates in abundance and farmers apply herbicides every year to control this weed; the farmers, in general, adopt herbicide which provides effective control of weeds and use the same herbicide over the years which results in evolution of resistance in the weeds, as is happening in case of clodinafop and sulfosulfuron which are being used continuously for control of *P. minor* in wheat. Evolved multiple resistance in *P. minor* to herbicides of different modes of action in India, Israel, Mexico, South Africa and USA suggests that no single herbicide will be able to control *P. minor* for long time and we need to swiftly change our strategy than *P. minor* to arrest its proliferation and economic loss (Singh 1996). Immediate steps are required to tackle this problem by integrating all possible resistance management options. Continuous monitoring and extensive research from understanding the biology, ecology and population dynamics of resistance biotypes, through investigating the molecular mechanisms responsible for endowing herbicide resistance in these biotypes is very essential to achieve long term sustainable weed control.

Table 7. Time of application of herbicides at farmers field

Application time	No. of farmers		
	2008-09	2009-10	2010-11
Normal (30-40 DAS)	41 (56)	46 (63)	52 (71)
Late (40 -60 DAS)	32 (44)	27 (37)	21 (29)

Figures in brackets indicate percentage of farmers

Table 8. Volume of water used for spraying herbicides

Volume of water (L/ha)	No. of farmers		
	2008-09	2009-10	2010-11
225	20 (27)	18 (25)	11(15)
300	43 (59)	47 (64)	49 (67)
375	10 (14)	8 (11)	13 (18)

Figures in brackets indicate percentage of farmers

The survey indicated that clodinafop and sulfosulfuron are widely used by the farmers in the state. The efficacy of both these herbicides is on the decrease with every passing year. The farmers have started using 2.0 to 3.0 times recommended dose of clodinafop or sequence application/tank-mix of clodinafop and sulfosulfuron but control is not satisfactory. The reduced efficacy of sulfosulfruon was more prevalent in fields having history of continuous use of sulfosulfuron but poor efficacy of clodinafop was even recorded in fields having continuous use of sulfosulfuron. The spray methodology adopted by the farmers was better than they were using in the previous years hence these can not be related to the reduced herbicide efficacy over the years. The survey results point clearly towards the development of cross resistance in *P. minor* in clodinafop to a large extent and that sulfosulfuron was likely to meet the same fate in the near future.

REFERENCES

Malik RK and Singh S. 1993. Evolving strategies for herbicide use in wheat: resistance and integrated weed management, pp. 225-238. In: *Proceedings of International Symposium on Integrated Weed Management for Sustainable Agriculture*, Indian Society of Weed Science, Hisar, India.

Malik RK and Singh S. 1995. Littleseed canary grass (*Phalaris minor* Retz.) resistance to isoproturon in India. *Weed Technology* **9**: 419-425.

Singh S.1996. Herbicide resistance mechanism in *Phalaris minor* and its consequences on management strategies. *Indian Journal of Weed Science* **38**: 183-193.

Walia US, Brar LS and Dhaliwal BK. 1997. Resistance to isoproturron in *Phalaris minor* Retz. in Punjab. *Plant Protection Quarterly* **12**: 138-140.

Yaduraju NT. 1999. Control of herbicide resistant *Phalaris minor*: need for a sound weed management system. *Pestology* Special Issue February, 264-266.

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Residual effect of wheat applied sulfonylurea herbicides on succeeding crops as affected by soil pH

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ABSTRACT

Study was conducted at Punjab Agricultural Univeriesty, Ludhiana to find the residual effect of sulphonylurea herbicdes, applied on wheat on the suceeding crops. The application of sulfonylurea herbicides proved quite effective against *Phalaris minor* in wheat crop without causing any toxicity to the crop. These herbicides being persistent in nature did not have same residual toxicity to most of the crops grown in succession except in mung and maize where growth and development was adversely affected. The other crops like rice and cotton grew well and did not exhibit any toxicity due to various sulfonylurea herbicides *viz*., sulfosulfuron and mesosulfuron + iodosulfuron. fresh weight of maize was significantly more in normal pH soil than high pH soil which indicates that herbicides persist longer in high pH soil and cause 8.1% reduction in fresh weight of maize in high pH soil.

Key words: *Kharif* crops, pH, Residue, Sulfonylurea herbicides, Wheat

Sulfonylurea herbicides are widely used in wheat. These herbicides break down slowly in alkaline soils and are very mobile in water under high pH conditions and can cause damage to following sensitive crops. Sulfonylurea herbicides persists longer as soil pH increases (Burkhardt and Fay 1985). Saha and Kulshreshtha (2002) reported that sulfosulfuron degraded at a faster rate in acidic (pH 4.0) than in alkaline condition (pH 9.2) and least in neutral. Sulfosulfuron can persists in soil at phytotoxic concentrations for more than one year after application, especially at low temperatures and high pH and cause damage to sensitive crops such as lentil, sorghum and sunflower grown as rotational crops after winter wheat (Kelly and Peeper 2003). Walker and Welch (1989) reported that sulfonylurea herbicides degrade faster in low pH soils than in high pH soils as degradation rate of chlorsulfuron and metsulfuron-methyl were negatively correlated with soil pH and suggested that the risk of residue carry-over will be greater in alkaline soils where degradation rates may be slow. High pH soils also provide a less favorable environment for hydrolysis (Hemmemda *et al*. 1994). Under alkaline soils, these herbicides cannot have significant mobility which could lead to the increased persistence of residues over a longer period of time (Sarmah *et al*. 1999). Amarjeet *et al*. (2003) also reported the faster rate of chlorsulfuron degradation in low pH soil than high pH soil. So there may be risk of residue carry-over in alkaline soils. Keeping these things in mind, the experiment was conducted to assess the efficacy of the sulfonylurea herbicides applied to wheat with respect to different pH levels and to study the effect on the crops grown in rotation.

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MATERIALS AND METHODS

The experiment was carried out at the Student's Research Farm, Department of Agronomy, PAU, Ludhiana during the years 2003-04 and 2004-05. The pot experiment was laid out in split plot design with four different herbicide treatments and unsprayed control. The herbicide sulfosulfuron was applied at 25 and 37.5 g/ha. Similarly mesosulfuron + iodosulfuron was applied at 12 and 18 g/ha and the unsprayed control. Both the herbicides were applied 35 days after sowing of wheat as per treatment. Twenty seeds of *Phalaris minor* were sown in all the wheat sown pots and later on thinned to ten plants and ten plants of wheat were retained. The treatments were replicated four times. The high pH soil (pH 8.9) was taken from Bathinda district of Punjab and normal pH soil (pH 7.4) was taken from PAU, Ludhiana. The soil was put in five iron rectangles (grills) having each box measuring 9"x 4". After wheat harvest, the succeeding crops of summer mung (*Vigna radiata* L.), *Kharif* mung (*Vigna radiata* L.), maize (*Zea mays* L.), rice (*Oryza sativa* L.) and cotton (*Gossypium arboreum*) were taken. The sowing of cotton was done in mid April and of rice and maize was done in June and of *Kharif* mung in July. Fresh weight of whole above ground portion of the plants was taken in all the *Kharif* crops.

RESULTS AND DISCUSSION

The height of *Phalaris minor* was statistically similar at two different pH soils (Table 1) during both the years. Both the doses of sulfosulfuron (25 and 37.5 g/ha) were at par with each other at harvest during both the years. During 2004-05, *P. minor* height was significantly less where mesosulfuron + iodosulfuron was applied at higher dose (18 g/ha) than its lower dose (12 g/ha). The height variation didn't indicate any consistency and hence not conclusive. *P. minor* height was significantly more in unsprayed control than rest all the other herbicide treatments due to susceptibility of this weed to herbicides. The interaction effects were not significant during both the years. The results were in line with Walia *et al*. (2002).

The wheat plant height did not differ significantly in different pH soils during both the years (Table 1). The plant height was at par where sulfosulfuron was applied at 25 and 37.5 g/ha in wheat during both the years. Higher dose of mesosulfuron + iodosulfuron (18 g/ha) resulted in significantly less height than its lower dose (12 g/ha) at harvest. This might be due to toxic effect of herbicide (Shukla *et al*. 1998, Chandi 2004). The interaction effects were not significant during both the years.

Significantly fewer yields were obtained in unsprayed crop (Table 1) than all other treatments which though were at par with each other during Ist year. On an average of two years, the per cent increase was 11.2, 14.6, 11.0 and 4.45 in sulfosulfuron at 25 and 37.5 g/ha and in mesosulfuron + iodosulfuron at 12 and 18 g/ha over unsprayed control, respectively,. Again significantly less grain yield was obtained in unsprayed than all other treatments in IInd year. Similar trend was recorded in the IInd year except where mesosulfuron + iodosulfuron was applied at 18 g/ha as this part of the experiment being low lying remain at its disadvantage. Straw yield also maintained the same trend during both the years. The interaction effects were not significant during both the years.

Effect on *Kharif* crops

The fresh weight of summer and *Kharif* mung was not affected significantly in both pH soils during both the years (Table 2), though significant differences were recorded in case of herbicide treatments during IInd year in both the crops. The residual effects were conspicuous as per cent reduction in fresh weight of summer mung was 14.1, 17.4, 12.3 and 5.3 g/ha in sulfosulfuron at 25 and 37.5 g/ha and in mesosulfuron + iodosulfuron at 12 and 18 g/ha, respectively, over unsprayed control and 16.7, 21.5, 15.8 and 16.7 per cent reduction in *Kharif* mung, respectively. This might be due to the rainfall pattern as the less rainfall was received in April, May and June in 2005 as compared to 2004. So, less rainfall left the soil dry and favoured the persistence in the soil. Fresh weight was significantly more where no herbicide was sprayed than sprayed plots in both the crops. All doses of both the herbicides were at par in respect of accumulating fresh weight. Fresh weight was not affected significantly in different herbicide treatments in *Kharif* mung during 2004. The interaction effects were not significant during both the years. Singh and Walia (2005) also reported residual effect of sulfosulfuron on mung crop.

No significant difference in the fresh weight of maize was recorded in two different pH soils and herbicide treatments during 2004 (Table 2). During 2005, fresh weight of maize was significantly more in normal pH soil than high pH soil which indicates that herbicides persist longer in high pH soil and cause 8.1%

Table 1. Effect of different treatments on plant height of *Phalaris minor,* and growth and yield of wheat

Treatment	*Phalaris minor* height at harvest (cm)		Wheat plant height at harvest (cm)		Grain yield (t/ha)		Straw yield (t/ha)	
	Ist year	IInd year	Ist year	IInd year	Ist year	IInd year	Ist year	IInd year
Soil pH								
High pH (8.9)	74.5	74.2	71.7	68.6	15.4	15.4	42.1	42.7
Normal pH (7.4)	76.1	74.2	72.7	687.0	15.6	15.8	43.1	40.4
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Herbicide dose								
Sulfosulfuron 25 g/ha	74.8	72.35	73.8	72.1	15.7	16.3	43.0	42.7
Sulfosulfuron 37.5 g/ha	73.1	68.6	73.1	69.9	16.5	16.4	43.6	42.6
Mesosulfuron + iodosulfuron 12 g/ha	73.9	73.8	72.1	70.1	15.8	16.1	43.2	42.5
Mesosulfuron + iodosulfuron 18 g/ha	71.8	71.4	73.4	65.6	15.6	14.4	43.2	39.4
Control	83.0	85.1	68.4	64.0	13.7	15.0	40.1	38.1
LSD (P=0.05)	4.6	3.71	2.39	3.25	1.66	0.93	2.33	2.89

Table 2. Residual effect of different herbicides applied to wheat on fresh weight of summer and *Kharif* mung, maize, rice and cotton in high and normal pH soil

Treatment	Summer mung (5 plants)	*Kharif* mung (5 plants)		Maize (g/plant)		Rice (g/plant)		Cotton (g/plant)	
	IInd year	Ist year	IInd year	Ist year	IInd year	Ist year	IInd year	Ist year	IInd year
Soil pH									
High pH (8.9)	23.32	35.20	24.25	34.15	22.56	41.73	30.34	33.36	23.13
Normal pH (7.4)	24.29	34.45	24.30	35.32	24.55	40.47	29.69	33.87	23.92
LSD (P=0.05)	NS	NS	NS	NS	0.84	NS	NS	NS	NS
Herbicide dose									
Sulfosulfuron 25g/ha	23.41	35.78	23.75	34.26	23.44	40.24	28.79	33.31	23.13
Sulfosulfuron 37.5 g/ha	22.51	34.01	22.38	34.74	22.57	40.66	30.37	34.99	23.78
Mesosulfuron + iodosulfuron 12 g/ha	23.88	35.06	24.00	34.43	23.63	41.24	30.32	33.15	23.54
Mesosulfuron + iodosulfuron 18 g/ha	21.98	34.18	23.75	35.18	22.50	40.24	29.88	33.39	23.57
Control	27.24	35.10	28.50	35.06	25.63	40.07	29.62	33.25	23.52
LSD (P=0.05)	2.67	NS	3.33	NS	3.07	NS	NS	NS	NS

reduction in fresh weight of maize in high pH soil. This might be due to slower rate of degradation in high pH soil which provided a less favourable environment for hydrolysis (Hemmemda *et al*. 1994). This indicates that there may be risk of residue carry over in alkaline soils. Similar findings were also reported by Walker and Welch (1989), Amarjeet *et al.* (2003). Similarly significant reduction in fresh weight was observed in different herbicide doses as compared to unsprayed control. The percent reduction was 8.5, 11.9, 7.8 and 12.2 in sulfosulfuron at 25 and 37.5 g/ha and in mesosulfuron + iodosulfuron at 12 and 18 g/ha respectively, over unsprayed control. The reduction in fresh weight indicates that maize is a sensitive crop for sulfonylurea application to wheat on alkaline pH soil. The interaction effects were not significant during both the years. This might due to toxic effect of herbicide on the crop (Yadav *et al*. 2004, Singh and Walia 2005). Fresh weight of rice and cotton was not significant with respect to all herbicide treatments and different pH soils during both the years (Table 2). Singh *et al*. (2003) also reported that mesosulfuron + iodosulfuron at 15.0+3.0 and 30.0+6.0 g/ha applied in wheat had no residual effect on the succeeding crop of transplanted rice. Yadav *et al*. (2004) also reported that sulfosulfuron applied at 25 g/ha to wheat caused no residual toxicity to cotton.

REFERENCES

Amarjeet, Punia SS, Yadav A and Malik RK. 2003. Effects of pH on degradation of chlorsulfuron in soil. *Indian Journal of Weed Science* **35**: 97-99.

Burkhardt DC and Fay PK. 1985. Effect of chlorsulfuron residues on rotational crops in Montana, pp. 111-113. In: *Proceedings of Western Society of Weed Science.* Paper presented in the Annual Meeting, March 12-15, 1985, Hilton Hotel, Phoenix, Arizona.

Chandi A. 2004. *Studies on the tolerance of durum wheat (Triticum durum* desf.*) cultivars to herbicides*. M.Sc. Thesis. Punjab Agricultural University. Ludhiana, India.

Hemmamda S, Calmon M and Calmon JP.1994. Kinetics and hydrolysis mechanism of chlorsulfuron and metsulfuron-methyl. *Pesticide Science* **40**: 71-76.

Kelly JP and Peeper TF. 2003. Wheat (*Triticum aestivum*) and rotational crop response to MON 37500. *Weed Technology* **17**: 55-59.

Saha S and Kulshrestha G. 2002. Degradation of sulfosulfuron, sulfonylurea herbicide as influenced by abiotic factors. *Journal of Agriculture, Food and Chemistry* **50**: 4572-4575.

Shukla G, Nagarajan S and Tyagi BS. 1998. Mon 37500: Candidate herbicide for warm wheat growing environment, pp 297-301. In: *Proceedings of International Conference, Wheat: Research needs beyond 2000 AD,* 12-14 August 1997, Karnal, India.

Singh M and Walia US. 2005. Studies on carry over effects of sulfosulfuron on the succeeding crops, pp 300-301. In: *Extended Summaries* of *ISWS Biennial Conference*, April 6-9, 2005, Punjab Agricultural University, Ludhiana, India.

Singh S, Malik RK, Singh H and Narwal S. 2003. Evaluation of ready-mix of mesosulfuron + iodosulfuron for weed control in wheat. *Indian Journal of Weed Science* **35**: 190-193.

Walia US, Brar LS, Singh K and Singh R. 2002. Performance of different herbicides for the control of *Phalaris minor* Retz. on variable pH soils. *Indian Journal of Weed Science* **34**: 116-118.

Walker A and Welch SJ. 1989. The relative movement and persistence in soil of chlorsulfuron, metsulfuron-methyl and triasulfuron. *Weed Research* **29**: 375-383.

Yadav A, Malik RK, Punia SS, Mehta R, Dharambir, Amarjeet and Bellinder RR. 2004. Studies on carry-over effects of herbicides applied in wheat on the succeeding crops in rotation. *Indian Journal of Weed Science* **36**: 15-18.

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Effect of post-emergence herbicides at variable soil moisture on weeds and yield of wheat

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ABSTRACT

An experiment was carried out during winter seasons of 2008-09 and 2009-10 at JNKVV, Jabalpur to study the response of post-emergence herbicides at variable available soil moisture (ASM) on weed biomass, yield attributing characters and yield of irrigated wheat. The weed control efficiency was higher at 100% ASM at the time of herbicides application and it was declined with every five per cent decrease in available soil moisture and was minimum under 80% ASM. The application of clodinafop *fb* 2,4-D registered significantly higher weed control efficiency over isoproturon and clodinafop alone. Yield attributes, *viz*. number of effective tillers, length of ear head, weight of ear head, weight of grains per ear head, number of grains per ear head, test weight and grain and straw yields were significantly higher at 100% ASM were at par with 95 and 90% ASM. Clodinafop *fb* 2,4-D proved significantly superior and produced 4.9, 5.8 and 18.4% higher grain yield over isoproturon, clodinafop and weedy check, respectively.

Key words: Available soil moisture, Clodinafop, Isoproturon, 2,4-D, Wheat

The introduction of high yielding dwarf varieties coupled with increased use of fertilizer and irrigation have increased weed problems. Slow growth of wheat at early stage and application of more fertilizer as well as irrigation right from sowing encourages the rapid growth of weeds, and if not controlled, they cause loss in yields to the tune of 15 to 40 per cent (Jat *et al.* 2003). Among the important factors responsible for higher productivity in wheat, moisture is of prime importance in promoting the growth and development of the crop. Moisture at the time of herbicide application is also important because it affects absorption and translocation of herbicides at the site of action. Moisture and herbicide may interact each other in reducing dry matter production of weeds and increasing the grain yield of wheat. An appropriate adjustment of time of herbicide application in relation to suitable soil moisture seems desirable for proper activity of herbicides. As the soil moisture decreases, the weeds are not controlled due to lower herbicidal absorption and poor physiological activity (Porwal and Dadheech 2008). Keeping this in view, the present experiment was carried out to assess the effect of application of post emergence herbicides at variable available soil moisture (ASM) on yield and yield attributing characters of irrigated wheat.

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MATERIALS AND METHODS

A field experiment was conducted at Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur, Madhya Pradesh (JNKVV) during the *Rabi* seasons of 2008-09 and 2009-10. The topography of the experimental field was fairly uniform and infested with location specific weeds representative of this area. The soil of the experimental area was clay, neutral in reaction (pH 7.20), medium in organic carbon content (0.64%), normal in electrical conductivity (0.32 dS/m), medium in available N (370 kg/ha) and P (16.0 kg/ ha) and high in available K (295 kg/ha). Twenty treatment combinations consisting of five moisture levels 100, 95, 90, 85 and 80% available soil moisture (ASM) and four weed control practices, *viz*. weedy check, isoproturon 750 g/ha, clodinafop alone 60 g/ha and clodinafop 60 g/ha *fb* 2,4-D 500 g/ha were laid out in split plot design and replicated four times. Wheat variety '*GW-273*' was sown in the experimental field with seed rate of 125 kg/ ha during both the years. Fertilizers were given uniformly to all the plots through urea, single super phosphate and muriate of potash at the rate of 100 kg Nitrogen, 60 kg Phosphorus and 40 kg Potassium/ha during both the years. Half of the nitrogen and full quantity of phosphorus and potash was given as basal and remaining nitrogen was given in two splits just next day of first and second irrigation in both the years. Five irrigations were given to the crop at all the critical stages, *viz*. crown root initiation, maximum tillering, late jointing, flowering and milk stage. However, a shallow come up irrigation was given immediately after sowing to the wheat crop in all the plots. The soil moisture was maintained during the herbicidal application by 6050 X3K1 mini trace kit soil moisture meter after the first irrigation. Herbicides were applied in the respective plots by knapsack sprayer using flat fan nozzle.

RESULTS AND DISCUSSION

Effect of available soil moisture

At the time of herbicide application, 100% available soil moisture recorded significantly lower dry matter of weeds and highest weed control efficiency (49.1%) and found significantly superior over 85 and 80% ASM (Table 1). The lower dry weight of weeds at 90 to 100% was due to maximum uptake and translocation of herbicides and maximum weed control whereas it decreased with the decrease in moisture resulted in higher weed dry weight at 80 and 85% ASM. Porwal and Dadheech (2008) also reported that under limited soil moisture conditions, weeds are difficult to control with post-emergence herbicides because of reduced herbicide absorption and low physiological activity.

Presence of 100% ASM at the time of herbicides application recorded significantly higher number of effective tillers, length of ear head, weight of ear head, weight of grains per ear head, number of grains per ear head, test weight and grain and straw yields and was at par with 95 and 90% ASM. The presence of 100% ASM also recorded significantly higher grain yield of wheat (6.10 t/ha) and proved significantly superior over 85 and 80% ASM (Table 2). Imanat (2002) also reported the importance of higher soil moisture at the time of herbicide application due to more absorption and translocation of herbicides in the weeds resulted less weed competition and increased the yield.

Effect of weed control treatments

Weed control practices had differential influence on the total weed dry matter. Post-emergence application of clodinafop *fb* 2,4-D recorded minimum total weed dry weight during both the years and proved more effective than isoproturon, clodinafop and weedy check. Efficacy of isoproturon and clodinafop in reducing the total weed dry weight was also good and both proved superior over weedy check. Weed control practices caused marked variation on weed control efficiency during both the years. The application of clodinafop *fb* 2,4-D registered the highest weed control efficiency followed by isoproturon and clodinafop alone.

Weed control treatments caused marked variation on yield attributes. Post-emergence application of clodinafop *fb* 2,4-D, isoproturon and clodinafop had statistically similar number of effective tillers, length of ear head, weight of ear head, weight of grains per ear head, number of grains per ear head and test weight which were significantly superior over weedy check .

Among weed control practices, clodinafop *fb* 2,4-D produced significantly higher grain yield over isoproturon, clodinafop and weedy check.

Table 1. Effect of available soil moisture at the time of herbicidal application on weeds, yield attributes and yield of wheat (pooled data of two years)

Treatment	Dry weight of weeds	Weed control efficiency (%)	No. of effective tillers	Length of earhead (cm)	Weight of earhead (g)	Number of grains per earhead	weight of grains per ear head (g)	Test weight	Grain yield (t/ha)	Straw yield (t/ha)
Moisture level										
100% ASM	6.54 (44.9)	49.1	280.8	9.71	3.31	55.3	2.69	45.6	6.10	7.03
95% ASM	6.74 (47.1)	45.3	268.9	9.55	3.19	53.8	2.59	44.9	5.94	6.93
90% ASM	6.97 (49.9)	42.4	262.0	9.43	3.10	52.4	2.55	44.1	5.62	6.66
85% ASM	7.27 (53.7)	37.5	255.4	9.27	3.00	50.7	2.48	43.5	5.42	6.54
80% ASM	7.47 (56.9)	34.0	250.9	9.13	2.91	50.1	2.39	43.2	5.22	6.40
LSD (P=0.05)	0.50	8.48	19.4	0.29	0.22	2.9	0.16	1.5	0.61	0.39
Weed control practices										
Isoproturon (750 g/ha)	7.10 (50.3)	32.2	272.7	9.57	3.18	53.7	2.60	44.8	5.81	6.81
Clodinafop (60 g/ha)	7.18 (51.6)	29.4	270.5	9.54	3.15	53.3	2.56	44.6	5.75	6.80
Clodinafop (60 g/ha) *fb* 2,4-D (500 g/ha)	5.13 (26.6)	63.3	276.5	9.64	3.24	54.3	2.63	45.0	6.11	6.97
Weedy check	8.57 (73.6)	0.00	234.8	8.93	2.84	48.5	2.37	42.6	4.98	6.28
LSD (P=0.05)	0.38	4.54	8.38	0.17	0.11	2.02	0.09	1.47	0.20	0.21

*The data is subjected to square root transformation. Values in parentheses are original values.

Table 2. Interaction effect of available soil moisture levels at the time of herbicides application and weed control on grain yield (t/ha) of wheat (pooled data of two years)

Treatment	Moisture level					Mean
	100% ASM	95% ASM	90% ASM	85% ASM	80% ASM	
Isoproturon (750 g/ha)	6.31	6.14	5.76	5.53	5.30	5.81
Clodinafop (60 g/ha)	6.24	6.08	5.70	5.47	5.24	5.75
Clodinafop (60 g/ha) *fb* 2,4-D (500 g/ha)	6.69	6.47	6.06	5.79	5.52	6.10
Weedy check	5.14	5.07	4.98	4.90	4.81	4.98
Mean	6.10	5.94	5.62	5.42	5.22	

LSD (P=0.05)	
Weed control treatments at same level of moisture	0.45
Moisture content at same level of weed control	0.73

Clodinafop *fb* 2,4-D applied as post-emergence showed knockdown effect on grassy and broad-leaved weeds which resulted in increased grain yield of wheat. Similar results were also obtained by Brar and Walia (2007) and Jain *et al.* (2007). Application of isoproturon resulted in higher grain yield of wheat over clodinafop, however the differences were not significant. This was due to control of both grassy as well as some broad-leaved weeds by the application of isoproturon.

Interaction effect

The interaction between available soil moisture regimes and weed control practices was significant. Application of all the post-emergence herbicides had significantly higher grain yield at cent per cent (100% ASM) over 85 and 80 % ASM but found statistically similar to 95 and 90 per cent ASM during both the years. The higher activity of herbicidal treatments against predominant weeds at 100 to 90% ASM curtailed the weed growth identically, which in turn enhanced the availability of growth resources (moisture, nutrients, light, space *etc*.) and finally resulted in higher grain yield with the application of clodinafop *fb* 2,4-D followed by isoproturon and clodinafop alone at 100 to 90% ASM to that of 85 to 80% ASM.

On the basis of the results, it was concluded that post-emergence application of clodinafop *fb* 2,4-D, isoproturon and clodinafop at 100 to 90% ASM significantly lowered the weed biomass and increased the grain yield over 85 and 80% ASM.

REFERENCES

Brar Amandeep Singh and Walia US. 2007. Influence of planting technique and weed control treatments on nutrient uptake by *Phalaris minor* and broad-leaf weeds in wheat. *Indian Journal of Weed Science* **39**(1&2): 55-61.

Jain Namrata, Mishra JS, Kewat ML and Jain Vinamarta 2007. Effect of tillage and herbicides on grain yield and nutrient uptake by wheat and weeds. *Indian Journal of Agronomy* **52**(3): 131-134.

Jat RS, Nepalia V and Jat RL. 2003. Effect of weed control and sowing methods on production potential of wheat. *Indian Journal of Agronomy* **48**(3): 192-195.

Imanat Y 2002. Effect of soil moisture regimes on efficacy of herbicides for weed control in wheat. AGRIS record no. PK2004000608, 2010. p 83.

Porwal MK and Dadheech RC. 2008. Weed management under moisture stress conditions, pp 54-56. In: *Proceedings of Biennial conference on Weed Management in Modern Agriculture: Emerging Challenges and Opportunities,* held at Patna, 27-28 February, 2008, ISWS.

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Increase in growth and yield of cassava with weed management

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ABSTRACT

The experiment comprising 10 weed management practices of different herbicidal combinations along with hand weeding were conducted on light textured soil of Jagdalpur as rainfed in *Kharif* season 2011 and 2012 on Tubers. *Digitaria sangunalis, Eleusine indica, Setaria gluaca, Cyperus compressus* and *Echinochloa colona* among monocots whereas broad leaved weeds, *viz. Celosia argentea, Commelina benghalensis, Spilanthus acmella* and *Euphorbia geniculata* were found rampant weeds. Irrespective of weeds management practices, density and dry weight of weeds and weed control efficiency were significant under four hand weeding (1,2,3 and 4 month after planting). The growth and yield attributes of cassava over weedy check were also higher in same treatment over weedy check.

Key words: Cassava, Tuber crop, Tapioca, Weed management

Cassava also known as tapioca (*Manihot esculenta* Crantz) is the largest source of dietary carbohydrates in the tropical and subtropical part after rice, wheat and maize. Cassava root is poor source of protein but ins spite of that is a major staple food in the developing world, providing a basic diet for over half a billion people. It is one of the most drought tolerant crops, capable of growing on marginal lands (Ugwu 1996). Farmers often prefer cassava because this is non-preferred to be attacked by pests, animals and thieves. Information about weed management in cassava is meager in spite of the fact that it has assumed as industrial crop in India being grown in large areas due to easy cultivation on marginal and poor land. Therefore, present experiment was carried out to study the effect of herbicides and their integration with other methods for obtaining higher yield of casava.

MATERIALS AND METHODS

The experiment was conducted comprising 10 weed management practices with different herbicidal and hand weeding combinations in 5 x 5 m plots with three replications on light textured soil of S.G. College of Agriculture and Research Station, Jagdalpur (Chhattisgarh) during *Kharif* season 2011 and 2012. The treatments comprised of oxyflorfen 0.06 kg/ha (pre-emergence), oxyflorfen 0.06 kg/ha (pre-emergence) + 1 hand weeding (3 months after planting), oxyflorfen 0.06 kg/ha (pre-emergence) + 2 hand weeding (2 and 3 months after planting), glyphosphate 2.0 kg/ha (pre-emergence 1 month after planting), one hand weeding (1 month after planting) + glyphosphate 2.0 kg/ha (pre-emergence, 2 months after planting), two hand weeding (1 and 2 months after planting) + glyphosphate 2.0 kg/ha (post-emergence 3 months after planting), four hand weeding (1, 2 3 and 4 months after planting), two hand weeding (1 and 2 months after planting), weedy check and black polythene mulch under randomized block design with four replications. The soil was medium in available N (260 kg/ha) and P (15 kg/ha), high in available K (290 kg/ha) with pH 6.5 in reaction. Cassava variety "*Sreevishakhum*" stem cuttings was planted on 26 June, 2011 and 28 June 2012 in 75 cm apart and cuttings were placed in opened ditches and gaps were maintained by planting sprouted cuttings to obtain proper plant population. Half dose of nitrogen (50 kg/ha) and full dose of P and K (60 and 40 kg/ha) were applied as basal and remaining half of nitrogen (30kg/ha) was top dressed one month later. Oxyfloufen was incorporated just after sowing. Plant protection measures were followed as per recommendation. Weed counts (number/m^2) and dry weight (g/m^2) were recorded by putting a quadrate (0.25 m^2) at five random spots in each plot at 30 DAS and harvesting. The data were recorded for growth, yield and economics and statistically analyzed. Data on weed density and dry weight of weeds were transformed using square root transformation $\sqrt{x + 0.5}$ before statistical analysis (Panse and Sukhatme 1967). Weed control efficiency (WCE) was also calculated on the basis of dry matter production of weeds.

RESULTS AND DISCUSSION

Weeds

The major grass and sedge weeds of experimental field consisted of *Setaria gluaca, Cyperus rotundus*,

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Digitaria sangunalis, Eleusine indica and *Echinochloa colona*. Among broad leaved weeds, *Spilanthes acmella, Celosia argentea, Commelina benghalensis, Euphorbia geniculata* were more rampant. Irrespective of weeds management practices, density, dry weight and weed control efficiency were higher in four hand weeding (at 1,2,3 and 4 month after sowing). The crop duration was 6 month and tuber formation started from third month after planting. This required nutrition to develop tuber properly that is why gave good tuber yield as compared to other hand weeding alone over other treatments except black polythene mulch and two hand weeding at 1 and 2 month after planting + protected application of glyphosate 2.0 kg/ha. The crop experienced severe weed competition in single application of oxyflourfen or glyphosate having nominal WCE (52.68, 56.17; 38.50, 40.32 and 16.25, 18.48% for oxyflourfen 0.06 kg/ha and 44.86, 48.35; 33.50, 33.83 and 12.57, 14.25%) which might be due to unfavourable conditions leading to vigorous growth of weeds (Cadavid *et al.* 1998). Among herbicidal treatments, oxyflourfen 0.06 kg/ha (pre-emergence) was found better than glyphosate 2.0 kg/ha alone. (Scott *et al.* 2000). All the weed management practices caused significant reduction in density, dry weight of weeds in comparison to weedy check plot (Table 1 and 2). In general, weed management practices reduced weed density from 0.00 to 6.00 weeds/m^2 under monocots and 0.00 to 4.00 g/m^2 in dicot during both the years. However, lowest density (0.00) and dry weight (0.00) of weeds were recorded under hand weeding followed by black polythene mulch throughout growing period (6.30, 32.68; 3.20, 11.30; 35.22, 4.55; as density and 1.50, 11.50; 5.50, 2.60; 3.12, 1.92). Similarly, plot receiving four hand weeding (at 1, 2,3 and 4 month after sowing) registered the highest weed control efficiency (69.52, 73.65,; 47.76, 56.24; 48.10, 57.63% in 2011 and 2012 on grasses, broad leaved weeds and sedges, respectively) and followed by black polythene mulch which showed the effective control of weeds and lowest in alone application of herbicides and hand weeding. Similar results

Table 1. Influence of integrated weed management on density and dry matter accumulation of weeds

Treatment	Density of weed (number/m^2)						Dry weight of weed (g/m^2)					
	Grasses		BLWs		Sedges		Grasses		BLWs		Sedges	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Two HW (1 and 2 months after planting)	13.87	26.68	1.30	18.87	29.22	2.65	3.19	2.89	7.19	4.34	4.50	3.30
	(3.79)	(4.14)	(1.34)	(4.40)	(5.45)	(1.77)	(1.92)	(1.84)	(2.77)	(2.20)	(2.24)	(1.95)
Four HW (1, 2, 3 and 4 months after planting)	4.33	30.68	0.00	9.33	33.22	1.35	1.00	0.70	5.00	2.15	2.45	1.25
	(2.20)	(2.61)	(0.71)	(3.14)	(5.81)	(1.36)	(1.22)	(1.10)	(2.35)	(1.63)	(1.72)	(1.32)
Oxyflorfen 0.06 kg/ha PE	14.25	28.68	0.44	19.25	31.22	1.79	3.12	2.82	7.12	4.43	7.18	5.98
	(3.84)	(4.37)	(0.97)	(4.44)	(5.63)	(1.51)	(1.90)	(1.82)	(2.76)	(2.22)	(2.77)	(2.55)
Oxyflorfen 0.06 kg/ha PE + 1 HW (3 months after planting)	8.28	29.68	0.61	13.28	32.22	1.96	3.30	3.00	7.30	3.05	7.41	6.21
	(2.96)	(3.19)	(1.05)	(3.71)	(5.72)	(1.57)	(1.95)	(1.87)	(2.79)	(1.88)	(2.81)	(2.59)
Oxyflorfen 0.06 kg/ha PE + 2 HW (2 and 3 months after planting)	8.98	27.68	0.50	13.98	30.22	1.85	3.34	3.04	7.34	3.21	6.95	5.75
	(3.08)	(2.86)	(1.00)	(3.80)	(5.54)	(1.53)	(1.96)	(1.88)	(2.80)	(1.93)	(2.73)	(2.50)
Glyphosphate 2.0 kg/ha (POE 1 month after planting)	19.18	31.68	29.80	24.18	34.22	31.15	4.41	4.11	8.41	5.56	7.87	6.67
	(4.44)	(4.70)	(5.50)	(4.97)	(5.89)	(5.63)	(2.22)	(2.15)	(2.98)	(2.46)	(2.89)	(2.68)
One HW (1 month after planting) + glyphosphate 2.0 kg/ha (POE 2 months after planting)	16.88	25.68	4.80	21.88	28.22	6.15	3.88	3.58	7.88	5.03	6.49	5.29
	(4.17)	(4.02)	(2.30)	(4.73)	(5.36)	(2.58)	(2.09)	(2.02)	(2.89)	(2.35)	(2.64)	(2.41)
Two HW (1 & 2 months after planting) + glyphosphate 2.0 kg/ha (POE 3 months after planting)	7.23	33.68	5.17	12.23	36.22	6.52	1.97	1.67	5.97	2.81	3.78	2.58
	(2.78)	(3.11)	(2.38)	(3.57)	(6.06)	(2.65)	(1.57)	(1.47)	(2.54)	(1.82)	(2.07)	(1.75)
Black polythene mulch	6.30	32.68	3.20	11.30	35.22	4.55	1.50	1.20	5.50	2.60	3.12	1.92
	(2.61)	(5.76)	1.92	3.44	5.98	2.25	1.41	1.30	2.45	1.76	1.90	1.56
Weedy check	53.00	35.68	17.98	58.00	38.22	19.33	15.65	16.78	19.65	13.34	10.45	9.25
	(7.31)	(6.01)	(4.30)	(7.65)	(6.22)	(4.45)	(4.02)	(4.16)	(4.49)	(3.72)	(3.31)	(3.12)
LSD (P=0.05)	0.98	0.87	0.54	0.75	0.32	0.45	0.12	0.11	0.14	0.12	0.15	0.14

HW = Hand weeding, PE = Pre-emergence, POE = Post-emergence

Table 2. Influence of integrated weed management on weed control efficiency

Treatment	Weed control efficiency (%)					
	Grasses		Broad-leaved weeds		Sedges	
	2011	2012	2011	2012	2011	2012
Two hand weeding (1 and 2 months after planting)	52.2	55.7	38.2	40.9	32.4	37.6
Four hand weeding (1, 2, 3 and 4 months after planting)	69.5	73.6	47.8	56.2	48.1	57.6
Oxyflorfen 0.06 kg/ha PE	52.7	56.2	38.5	40.3	16.2	18.5
Oxyflorfen 0.06 kg/ha PE + 1 hand weeding (3 months after planting)	51.5	55.0	37.8	49.3	15.0	17.0
Oxyflorfen 0.06 kg/ha PE + 2 hand weeding (2 and 3 months after planting)	51.2	54.7	37.6	48.2	17.5	19.9
Glyphosphate 2.0 kg/ha (POE 1 month after planting)	44.9	48.3	33.5	33.8	12.6	14.2
One hand weeding (1 month after planting) + glyphosphate 2.0 kg/ha (POE, 2 months after planting)	47.9	51.4	35.5	36.8	20.1	22.9
Two hand weeding (1 and 2 months after planting) + glyphosphate 2.0 kg/ha (POE 3 months after planting)	60.9	64.6	43.3	51.1	37.5	43.8
Black polythene mulch	64.8	68.6	45.4	52.7	42.5	50.2
Weedy check	0.00	0.00	0.00	0.00	0.00	0.00

Table 3. Effect of integrated weed management practices on yield and economics

Treatment	Tuber yield (t/ha)		Weed index (%)		Cost: benefit ratio	
	2011	2012	2011	2012	2011	2012
Two hand weeding (1 and 2 months after planting)	14.77	13.47	38.1	36.9	0.66	0.36
Four hand weeding (1, 2, 3 and 4 months after planting)	23.85	22.55	0.00	0.00	1.10	1.20
Oxyflorfen 0.06 kg/ha PE	14.35	13.05	39.5	38.3	0.84	0.74
Oxyflorfen 0.06 kg/ha PE + 1 hand weeding (3 months after planting)	18.33	17.03	23.3	22.1	1.03	1.08
Oxyflorfen 0.06 kg/ha PE + 2 hand weeding (2 and 3 months after planting)	14.68	13.38	38.5	37.3	0.43	0.54
Glyphosphate 2.0 kg/ha (POE 1 month after planting)	15.46	14.16	35.0	33.8	0.93	0.89
One hand weeding (1 month after planting) + glyphosphate 2.0 kg/ha (POE, 2 months after planting)	17.67	16.37	25.9	24.7	0.91	0.89
Two hand weeding (1 and 2 months after planting) + glyphosphate 2.0 kg/ha (POE 3 months after planting)	21.12	19.82	11.5	10.3	1.02	1.13
Black polythene mulch	23.35	22.05	2.14	2.09	0.27	0.30
Weedy check	5.60	4.30	75.1	73.9	0.19	0.39
LSD (P=0.05)	2.19	2.73	-	-	-	-

PE = Pre-emergence, POE = Post-emergence

were reported by Pareek *et al.* (2000) and Mehriya *et al.* (2003). Weedy check recorded the highest density and dry weight of weeds owing to their greater competitive ability than cassava crop.

Crop

The tuber yield of 2011 was slightly higher than 2012 regardless to treatment imposed due to climate variation like early rain (20 mm) promoted little vegetative growth. But expression of growth parameters, weed indices and yield attributes under treatments were found similar in case of effectiveness. Single application of oxyflourfen 0.06 kg/ha as pre-emergence (14.33 and 13.05 t/ha) was significant over glyphosate 2.0 kg/ha alone (15.46 and 14.16). The maximum tuber yield (23.73 and 22.55 t/ha) was recorded under four hand weeding (at 1,2,3 and 4 month after sowing) followed by T_{10} (23.73 t/ha) and T_9 (22.77 t/ha). Minimum weed index (0.00) was recorded in treatment T_3 and maximum was in T_1 (78.13).

All weed management practices significantly improved the yield of tuber over weedy check. Four hand weeding at 30 days interval were effective for all flushes of weeds which provided suppression of weeds and congenial condition to tuber growth. The creation of weed suppressive environment for crop helped of check the growth of the weeds. Oxyflourfen and glyphosate being broad spectrum herbicides supplemented by hand weeding improved yield potential with increasing the number of hand weeding over single application of herbicides. It might be attributed to the reduction in weed competitiveness with the crop. Similar findings were also reported by Mehriya *et al.* (2007) in cumin. Whereas in combination, the best combination was two hand weedings + glyphosate 2.0 kg/ha at 3 month after planting over other combination. Among hand weeding, four hand weeding gave the higher tuber yield (2.33 and 2.25 t/ha) over only two hand weeding (1.55 and 1.35 t/ha). Four hand weeding gave the higher benefit cost ratio (1:1.10 and 1:1.20) followed by two hand weeding (1 and 2 month after planting) + glyphosate 2.00 kg/ha as post-emergence at 3 month after planting (Table 3).

REFERENCES

Scott GH, Best R, Rosegrant MW and Bokanga M. 2000. Root and tubers in the global food system. A vision statement to the year 2020. *Inter CGIAR center Publication,* Lima, Peru, 111 p.

Cadavid LF, MA El-sharkewy, Acosta A and Sanchez T. 1998. Long term effects of mulch, fertilization and tillage on cassava grown in sandy soil in northern Columbia. *Field Crops Research* **57**: 45-56.

Ugwu BO. 1996. Increasing cassava production trend in Nigeria and prospects for sustaining the trend. *Outlook on Agriculture* **25** (3): 179-185.

Mehriya ML, Yadav RP, Jangir RP and Poonia BL. 2007. Nutrient utilization by cumin (*Cuminum cyminum*) and weeds as influenced by different weed control methods. *Indian Journal of Agronomy* **52**: 176-179.

Pareek NK, Jat NL and Pareek RG. 2000. Response of coriander (*Cuminum cymminum*) and weeds as influenced by different weed control methods. *Indian Journal of Agronomy* **16**: 104-109.

Panse VG and Sukhatme PV. 1967. *Statistical methods for agricultural workers.* ICAR publication, New Delhi. 62 p.

Singh G and Singh D. 1984. Herbicides cum cultural weed control in soybean. pp 35-36. In: *Proceeding of Annual Weed Science Conference,* Feb 27-28, JNKV, Jabalpur.

Singh F. 1987. Effect of pre-planting tillage and herbicides on weeds and fodder yield of M.P. *Indian Journal of Weed Science* **19**(3&4): 220-223.

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Influence of weed and fertilizer managment on yield and nutrient uptake in mustard

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ABSTRACT

Field investigation were carried out during winter season of 2011-12 and 2012-13 at Kalimpong (1250 m asl), to evaluate the effect of different fertilizer levels and weed management practices on density and dry matter of weeds and crop-weed completion for nutrient in Indian mustard (*Brassica juncea* (L.) Czern and Coss.). Amongst various fertility levels minimum weed density and dry matter production was recorded with the application of 150% RDF, which was found to be significantly superior to all other main plot treatments. Amongst various chemical treatments, the minimum weed density and weed dry matter production was observed with pendimethalin (0.75 kg/ha) + hand weeding (HW) at 35 DAS, and was at par with the hand weeding twice during both the years, and in second year this was statistically similar with pendimethalin (1.25 kg/ha) and alachlor (1.25 kg/ha). More seed yield was recorded with 150% RDF (2.19 t/ha) in first year and in second year more yield was associated with the 125% RDF (2.07 t/ha). Amongst various herbicidal treatments, during the first year maximum seed yield was registered with pendimethalin (1.25 kg/ha), and was at par with all the treatments except weedy check, fluchloralin (0.75 kg/ha) and pendimethalin (0.75 kg/ha), and in second year highest seed yield was recorded with the hand weeding twice, and was statistically at par with the pendimethalin (1.25 kg/ha), pendimethalin (0.75 kg/ha) + HW at 35 DAS and alachlor (1.25 kg/ha). Amongst various main plot treatments, least nutrient uptake by weed was recorded with the application of 150% RDF. Least nutrient depletion by weed was registered with the hand weeding twice during both the year of data recording, and was at par with the pendimethalin (0.75 kg/ha) + HW at 35 DAS. Economics revealed that application of 150% RDF gave maximum net return (` 19,380). However highest benefit: cost ratio (2.03) was registered with the application of 125% RDF. With sub-plot treatment highest net return (` 19,950) was observed with the hand weeding twice (` 19,950/ha), and was followed by application of pendimethalin (0.75 kg/ha) + HW at 35 DAS (` 19,850/ha). Maximum benefit: cost ratio (2.06) was recorded with the application of pendimethalin (1.25 kg/ha) and was closely followed by pendimethalin (0.75 kg/ha) + HW at 35 DAS (1.91).

Key words: Economics, Fertility levels, Herbicide, Mustard, Nutirent uptake,Weed management, Yield

Oilseeds occupy 27.5 million ha which account for 14% of total cropped area in the country with a production of 24.7 million tonnes, accounting for nearly 5% of the gross national product and 10% of the value of all the agricultural products. Rapeseed and mustard rank third in area (21%) and production (23%) after groundnut (*Arachis hypogaea* L.) and soybean (*Glycine max* L. Merr). The per hectare productivity of the rapeseed and mustard in the country is quite low (1.15 t/ha) against the world average of 1.40 t/ha (Puri and Sharma 2006). Mustard is one of the most important crop adopted by the farmers in the North eastern hill region of India. This is a potential crop in winter (*Rabi*) season due to its wider adaptability and suitability to exploit residual moisture (Mukherjee 2010). It has been estimated that yield depression in rapeseed mustard due to weed infestation varied from 20-70% depending on the composition and density of weed flora and time of their occurrence (O-Donovan *et al*. 2007).

In the past, farmers of Eastern Himalaya were bound to follow traditional weed techniques such as hand-pulling, hand-hoeing or mechanical hoeing. These techniques, besides being labour and energy intensive and weather dependent, are very difficult to apply due to shortage and high cost of labour. Application of adequate fertilizer to plant crop increases their leaf growth, which facilitates earlier shading of the soil surface and thus reduces weed seed germination (Wicks *et al*. 2012). In the past, little attention has been given to improve mustard productivity through IWM in rainfed areas of the Darjeeling hill. Therefore, the proposed study was carried out with the objective to develop suitable fertilizer and weed control technology for mustard production under terraced mid hill condition.

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MATERIALS AND METHODS

A field trial was conducted during *Rabi* winter season of 2011-12 and 2012-13 at Kalimpontg (1250 m asl), Regional Research Station (Hill Zone), Uttar Banga Krishi Viswavidyalaya, Darjeeling, West Bengal. The soil was sandy loam in texture, medium in organic carbon (0.89%), available N (283.15 kg/ha), P_2O_5 (20.31 kg/ha) and K_2O (183.29 kg/ha) content with pH 5.3. The total rainfall recorded during crop growth period was 19.3 and 15.8 mm, minimum temperature ranges from 3.9 to 11.3 and 4.9 to 16.8, and maximum temperature 19.2 to 32.6 and 16.8 to 31.3 ^{0}C during winter 2011 and 2012, respectively. The field experiment was conducted in split plot design with three replications, having 44 treatments combinations of four fertility levels *viz.*75 % RDF, 100% RDF, 125% RDF and 150% RDF in main plot and eleven weed control treatments (*viz*. weedy check, hand weeding twice (25 and 50 DAS), fluchloralin (0.75 kg/ha), fluchloralin (1.25 kg/ha), fluchloralin (0.75 kg/ha) + hand weeding (HW) at 35 DAS, pendimethalin (0.75 kg/ha), pendimethalin (1.25 kg/ha), pendimethalin (0.75 kg/ha) + HW at 35 DAS, alachlor (0.75 kg/ha), alachlor (1.25 kg/ha) and alachlor (0.75 kg/ha) + HW at 35 DAS. Fluchloralin was applied one day prior to sowing of the crop and incorporated immediately into the soil to a depth of 5 cm, while pendimethalin and alachlor were applied three days after sowing. Herbicide were applied through a manually operated foot sprayer with flat fan nozzle using 800 liter water/ha.

The recommended dose of fertilizer (RDF) was 60:40:40 kg N, P_2O_5 and K_2O/ha, respectively for mustard. NPK were supplied through urea, single superphosphate and muriate of potash. Full amount of phosphorus and potash and half of nitrogen was applied at the time of sowing. The remaining dose of nitrogen was top dressed at the pre-flowering stage. Two quadrates of 25 x 25 cm were placed randomly in each plot and weeds within the quadrates were removed and after drying in hot air oven (70 ± 1^{0}C for 72 hrs), weed dry weight was recorded. Mustard cultivar '*Varuna (T 59)*' was shown on 22nd October 2011 and 28th October 2012, respectively. The seed and straw yield was computed from the harvest of net plot and expressed in ha. Plant and soil samples were analyzed for uptake of nitrogen, phosphorus and potash as per standard laboratory procedures (Jackson 1973). Available phosphorous was determined by Olsen's method as outlined by Jackson (1973), using spectrophotometer (660 nm wave length). Available potassium was extracted with neutral normal ammonium acetate and the content of K in the solution was estimated by flame photometer (Jackson 1973). The experimental data were analyzed statistically by applying the technique of analysis of variance (ANOVA) prescribed for the design to test the significance of overall difference among treatments by the F test and conclusions were drawn at 5% probability level. Benefit: cost ratio (B: C) was obtained by dividing the gross income with cost of cultivation. The effect of treatments was evaluated on pooled analysis basis on growth, yield attributes and yields.

RESULTS AND DISCUSSION

The most dominant weed species at experimental site were *Anagallis arvensis, Chenopodium album, Convolvulus arvensis, Centella asiatica, Melilotus indica, Medicago polymorpha, Coronopus didymus, Oxalis latifolia* and *Vicia sativa*. During both the years, dicot weeds were predominant in the field. The most prominent weeds of rapeseed were recorded as *Chenopodium album, Chenopodium murale, Anagallis arvensis, Convovulus arvensis, Euphorbia heliscopia, Medicago polymorpha, Cynodon dactylon, Phalaris minor* and *Asphodalus* spp. (Bhowmik 2003). Amongst fertility levels, minimum weed density was recorded with the application of 150% RDF, during both the years (Table 1). This might be due to better growth of crop over weeds and smothering effect of crop vegetative growth over the weeds leading to suppression of weeds population greatly. All weed management treatments significantly reduced the weed density at 60 days after sowing. The minimum weed density was recorded under pendimethalin (0.75 kg/ha) + HW at 35 DAS , and was at par with the hand weeding twice, during both the years, further in second year this was statistically similar with pendimethalin (1.25 kg/ha) and alachlor (1.25 kg/ha). Maximum weed infestation was registered with the control, and was closely followed by pendimethalin (0.75 kg/ha) and alachlor (0.75 kg/ ha).

Fertility levels played significant role in reducing weed dry matter production. Application of 150% RDF significantly reduced weed dry matter production during both the years. All the weed management practices significantly reduced the weed dry matter compared to weedy check (Table 1). Significantly lower weed dry matter was registered under hand weeding, pendimethalin (0.75 kg/ha) + HW at 35 DAS and alachlor (0.75 kg/ha) + HW at 35 DAS during the first year and pendimethalin (0.75 kg/ha) + HW at 35 DAS, and alachlor (0.75 kg/ha) + HW at 35 during the second year.

Application of 150 and 125% RDF registered significantly more seed yield compared to other levels of fertilizers. During first year, more seed yield was recorded with 150% RDF (2.19 t/ha) and in second year more yield was associated with the 125% RDF (2.07

Table 1. Effect of fertility levels and weed management practices on weed density and dry matter in mustard

Treatment	Weed density (no./m^2)			Weed dry matter (g/m^2)		
	2011-12	2012-13	Mean	2011-12	2012-13	Mean
Fertility levels (kg/ha)						
75% RDF	23.1 (534)	18.9 (358)	21.02 (446)	28.9	33.2	31.0
100% RDF	17.3 (300)*	19.4 (374)	18.34 (337)	25.7	27.7	26.7
125% RDF	12.6 (157)	15.4 (235)	13.96 (196)	22.3	25.0	23.7
150% RDF	9.4 (87)	11.2 (125)	10.29 (106)	21.4	20.2	20.7
LSD (P = 0.05)	0.93	1.31		1.40	1.96	
Weed management						
Control	27.0 (789)	30.3 (897)	28.71 (804)	65.3	59.1	62.2
Hand weeding (HW) twice (25 and 50 DAS)	9.6 (92)	11.1 (124)	10.40 (108)	11.3	15.3	13.2
Fluchloralin (0.75 kg/ha)	18.3 (336)	21.0 (442)	19.69 (389)	25.1	28.1	26.6
Fluchloralin (1.25 kg/ha)	16.4 (267)	19.3 (373)	17.84(320)	19.6	25.4	22.5
Fluchloralin (0.75 kg/ha) + HW at 35 DAS	11.2 (125)	16.3 (266)	13.77 (195)	13.3	19.1	16.2
Pendimethalin (0.75 kg/ha)	21.4 (456)	19.1 (365)	20.23 (410)	16.3	13.9	15.1
Pendimethalin (1.25 kg/ha)	13.4 (178)	12.4 (152)	12.86 (165)	14.6	18.4	16.5
Pendimethalin (0.75 kg/ha)+ HW at 35 DAS	10.0 (100)	11.2 (126)	10.62 (113)	12.0	9.4	10.7
Alachlor (0.75 kg/ha)	20.2 (409)	23.7 (561)	21.96 (485)	21.4	27.3	24.3
Alachlor (1.25 kg/ha)	17.3 (300)	15.2 (231)	16.28 (266)	25.3	20.1	22.7
Alachlor (0.75 kg/ha)+ HW at 35 DAS	11.1 (123)	12.7 (160)	11.88 (141)	10.3	16.4	13.3
LSD (P = 0.05)	1.23	1.69		2.91	3.03	

Data subjected to square root transformation. *Figures in parentheses are original values.

Table 2. Effect of fertility levels and weed management practices on yield and economics of mustard

Treatment	Seed yield (t/ha)			Straw yield (t/ha)			Net returns (x10^3 `/ha)			B:C ratio		
	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean
Fertility levels (kg/ha)												
75% RDF	1.20	1.03	1.42	2.97	2.98	2.97	8.05	6.98	7.515	0.87	0.76	0.81
100% RDF	1.70	1.58	1.64	3.01	3.33	3.16	12.11	13.25	12.68	1.75	1.68	1.71
125% RDF	2.07	1.95	2.01	4.08	3.98	4.03	19.16	18.65	18.90	2.10	1.97	2.03
150% RDF	2.19	1.87	2.06	4.51	3.21	3.86	20.85	17.91	19.38	1.82	1.55	1.68
LSD (P = 0.05)	0.23	0.14		1.01	1.05							
Weed management												
Hand weeding (HW) twice (25 and 50 DAS)	2.22	2.19	2.27	4.35	3.78	3.84	20.10	19.89	19.95	1.86	1.78	1.81
Fluchloralin (0.75 kg/ha)	1.52	1.36	1.44	3.02	3.08	3.05	16.83	14.25	15.54	1.25	1.42	1.33
Fluchloralin (1.25 kg/ha)	1.86	1.71	1.78	3.69	3.52	3.60	17.33	16.89	17.11	1.23	1.96	1.59
Fluchloralin (0.75 kg/ha) + HW at 35 DAS	1.93	1.79	1.86	4.01	3.66	3.83	19.63	17.06	18.34	2.05	1.61	1.83
Pendimethalin (0.75 kg /ha)	1.62	1.73	1.67	3.26	3.18	3.52	17.44	16.96	17.25	1.55	1.30	1.42
Pendimethalin (1.25 kg /ha)	2.01	1.91	1.96	3.59	3.42	3.26	19.02	18.78	18.94	2.14	1.98	2.06
Pendimethalin (0.75 kg /ha)+ HW at 35 DAS	2.09	2.10	2.09	3.98	3.54	3.68	19.74	19.99	19.85	2.02	1.81	1.91
Alachlor (0.75 kg/ha)	1.83	1.46	1.64	3.43	3.29	3.36	17.86	14.98	16.42	1.34	1.27	1.05
Alachlor (1.25 kg/ha)	1.90	1.93	1.91	3.44	3.16	3.55	19.54	19.66	19.61	2.03	1.98	1.09
Alachlor (0.75 kg/ha)+ HW at 35 DAS	2.01	1.71	1.86	4.01	3.65	3.83	19.09	16.86	17.95	1.14	1.21	1.17
Control	0.93	0.82	0.87	2.61	2.98	2.79	6.18	5.05	5.61	0.73	0.81	0.87
LSD (P = 0.05)	0.26	0.34		0.56	0.39							

Note: Price of mustard seeds (` 103.50/kg), urea (`10.90/kg), SSP (` 14.60/kg), MOP (` 9.75/kg) and cost of labour (` 162.50 /day) t/ha). RDF (150%) gave 45% more mean grain yield over lower fertility level (75% RDF). The higher seed yield due to higher fertility levels was because of better growth and more translocation of photosynthates from source to sink (Tripathi *et al.* 2005, Rana *et al.* 2005). All the weed control treatments significantly increased the seed yield of mustard over weedy check. During first year, maximum seed yield was registered with pendimethalin (1.25 kg/ha), and was at par with all the treatments except weedy check, fluchloralin (0.75 kg/ha) and pendimethalin (0.75 kg/ha). In second year, peak seed yield was recorded with the hand weeding twice, and was statistically at par with the pendimethalin (1.25 kg/ha), pendimethalin (0.75 kg/ha) + HW at 35 DAS and alachlor (1.25 kg/ha). Application of herbicidal treatments along with hand weeding at 35 DAS gave 32 to 68% more seed yield over weedy check. This was in conformity with the finding of O'-Donovan *et al.* (2007)

Stover yield revealed that, fertility levels gave positive response during both the years of observation. More straw yield was registered with 150% RDF in first year, and with 125% RDF in the second year. Both the treatments were at par with each other during both the years of experiment, and significantly better than other set of fertility management practices. The greater straw yield at higher fertility was attributed to increased plant height and leaf area and finally more accumulation of dry matter per plant.This greater straw yield was also concluded by Kumar (2006). Amongst various sub-plot treatments, more straw yield was recorded with hand weeding twice during both the years. However in first year, this was statistically similar with pendimethalin (0.75 kg/ha) + HW at 35 DAS and fluchloralin (0.75 kg/ha) + HW at 35 DAS, and in second year with fluchloralin (1.25 kg/ha), pendimethalin (0.75 kg/ha) + HW at 35 DAS, fluchloralin (0.75 kg/ha) + HW at 35 DAS and alachlor (0.75 kg/ha) + HW at 35 DAS. This might be due to the efficient control of weeds with lower dry matter production of weeds and higher crop growth.

Amongst fertility treatments, least nutrient uptake by weed was recorded with the application of 150% RDF. Uptake of nitrogen failed to produce any significant response during both the years of study. Uptake of phosphorous gave positive response only in first year and least nutrient uptake registered with 150% RDF. Uptake of potassium was least registered with higher fertility levels *i.e.* 150% RDF during both the years (Table 3). Among weed control treatments, maximum uptake of primary nutrients by weed was registered with the weedy check. Least nutrient uptake by weed was registered with the hand weeding twice during both the years and was at par with

Table 3. Effect of fertility levels and weed management practices on nutrient uptake by weeds and crop of mustard

Treatment	Uptake by weeds (kg/ha)						Uptake by crop (kg/ha)					
	N		P		K		N		P		K	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Fertility levels (g/ha)												
75% RDF	4.06	4.32	2.80	3.25	10.2	8.95	60.2	87.0	14.2	16.0	55.3	66.3
100% RDF	3.96	3.98	2.98	3.21	9.12	9.65	102.3	87.4	21.4	18.9	79.0	63.9
125% RDF	3.56	3.39	2.31	2.98	7.98	7.89	121.6	112.3	30.0	29.6	95.7	78.9
150% RDF	2.84	3.21	1.90	1.85	6.89	5.69	133.4	123.0	33.4	32.1	98.0	89.6
LSD (P=0.05)	NS	NS	0.12	NS	0.45	0.68	8.02	6.34	3.36	5.12	5.62	9.98
Weed management												
Hand weeding (HW) twice (25 and 50 DAS)	2.01	2.34	1.39	1.41	7.98	9.18	133.0	125.0	28.9	27.0	103.1	111.3
Fluchloralin (0.75 kg/ha)	4.98	4.10	2.36	2.98	11.1	10.1	107.6	109.3	20.0	21.9	71.2	79.3
Fluchloralin (1.25 kg/ha)	4.89	4.95	2.54	3.14	9.89	10.1	112.1	108.1	20.1	19.0	80.2	83.0
Fluchloralin (0.75 kg/ha) + HW at 35 DAS	3.91	4.11	2.11	3.01	8.91	9.06	105.6	111.9	21.6	20.1	94.0	91.1
Pendimethalin (0.75 kg/ha)	5.52	5.17	3.11	3.91	12.0	13.1	104.3	89.6	18.0	15.2	79.1	70.2
Pendimethalin (1.25 kg/ha)	3.11	3.68	2.81	2.16	9.11	10.2	123.1	116.9	26.0	21.9	89.4	82.5
Pendimethalin (0.75 kg/ha)+ HW at 35 DAS	2.51	2.98	1.55	1.59	8.06	9.01	126.8	119.1	27.0	26.9	98.2	95.0
Alachlor (0.75 kg/ha)	4.54	5.02	2.88	3.99	12.0	13.1	111.3	94.4	20.0	15.8	85.1	84.2
Alachlor (1.25 kg/ha)	3.91	4.28	2.58	2.91	10.1	11.0	114.2	107.3	21.1	21.3	90.9	91.1
Alachlor (0.75 kg/ha)+ HW at 35 DAS	3.71	3.80	1.90	3.10	9.96	10.0	120.9	116.9	25.4	19.1	96.0	94.9
Control	6.19	7.72	3.98	4.89	24.0	29.4	88.2	69.4	15.4	12.4	65.3	53.3
LSD (P = 0.05)	0.99	1.04	0.44	0.57	1.10	1.32	8.53	7.58	2.35	1.98	7.33	8.91

pendimethalin (0.75 kg/ha) + HW at 35 DAS. Uptake of phosphorus and potassium was least associated with hand weeding twice during both the years and was at par with the pendimethalin (0.75 kg/ha) + HW at 35 DAS. The removal of N, P and K by weeds were reduced significantly by various herbicidal and manual weeding treatments and it almost nil under hand weeding twice, whereas the significantly highest N,P and K uptake by weeds were recorded in the weedy check treatments (Table 3). These results confirm the finding of Kour *et al.* (2013).

Application of 150% RDF registered more nitrogen uptake during both the years. Highest uptake of phosphorus and potassium was recorded with 150% RDF and was statistically at par with the 125% RDF during both the years. These observations are in agreement with finding of Shekhawat *et al.* 2012. Among weed management practices, maximum uptake of NPK was recorded with the hand weeding twice during both the years. Application of pendimethalin (0.75 kg/ha) + HW at 35 DAS gave maximum nitrogen uptake by crops, and was at par with the pendimethalin (1.25 kg/ha) and alachlor (0.75 kg/ha) + HW at 35 DAS. Uptake of phosphorus was highest with pendimethalin (0.75 kg/ha) + HW at 35 DAS during the second year. However it was at par with the pendimethalin (1.25 kg/ha) and alachlor (0.75 kg/ha) + HW at 35 DAS during the first year. Potassium uptake was more with pendimethalin (0.75 kg/ha) + HW at 35 DAS during initial year of observation. However in second year this was at par with the fluchloralin (0.75 kg/ha) + HW at 35 DAS and alachlor (0.75 kg/ha) + HW at 35 DAS.

Application of 150% RDF gave maximum net return (` 20,850/ha) during first year while in second year, 125% RDF produced maximum net return (` 18,650/ha) (Table 2). Mean net return of two years revealed that maximum net return with 150% RDF (` 19,380). However, highest benefit: cost ratio (2.03) was registered with the application of 125% RDF. Among weed control treatments, highest net return (` 19,950) was obtained with the hand weeding twice (` 19,950/ha), followed by application of pendimethalin (0.75 kg/ha) + HW at 35 DAS (` 19,850/ha). Maximum benefit: cost ratio (2.06) was recorded with the application of pendimethalin (1.25 kg/ha) and closely followed by pendimethalin (0.75 kg/ha) + HW at 35 DAS (1.91).

Present study suggests that application of 125% RDF along with application of pendimethalin (0.75 kg/ha) + HW at 35 DAS found to be best in terms of mustard yield and nutrient uptake by weeds and crop.

REFERENCES

Amanullah MA, Sekhar S and Muthukrishnan P. 2010. Prospect and potential of chicken manure. *Asian Journal of Plant Sciences* **34**(1): 1-11.

Bhowmik TP. 2003. *Oil Seed Brassicas: Constraints and their Management*. 1st Edition, CBS publishers and Distributors, New Delhi: 254 p.

Jackson ML. 1973. *Soil Chemical Analysis*, Prentice Hall of India Pvt. Ltd., New Delhi: 498 p.

Kaur R, Sharma BC, Kumar A and Kour P. 2013. Nutrient uptake by chickpea + mustard intercropping system as influenced by weed management. *Indian Journal of Weed Science* **45**(3): 183-188.

Kumar N. 2006. *Integrated nutrient management practices in mustard (Brassica juncea L.) and its effect on the productivity of succeeding rice crop*. Ph.D. Chaudhary Charan Singh, Univerisity, Meerut.

Mukherjee D. 2010. Productivity, profitability and apparent nutrient balance under different crop sequence in mid-hill condition. *Indian Journal of Agricultural Sciences* **80**(5): 420-22.

O'-Donovan JT, Blackshaw RE, Harker KN, Clayton GW, Moyer JR, Dosdall LM, Maurice DC and Turkington TK. 2007. Integrated approaches to managing weeds in spring-sown crops in western Canada. *Crop Protection* **26**: 390-398.

Piri I and Sharma SN. 2006. Effect of levels and sources of sulphur on yield attributes, yield and quality of Indian mustard (*Brassica juncea* L.). *Indian Journal of Agronomy* **51**(3): 217-220.

Rana KS, Rana DS and Gautam RC. 2005. Influence of phosphorus, sulphur and boron on growth, yield and nutrient uptake and economics of Indian mustard (*Brassica juncea* (L.) under rainfed condition. *Indian Journal of Agronomy* **50**(4): 314-316.

Shekhawat K, Premi OP, Kandpal BK and Chauhan JS. 2012. Advances in agronomic management of Indian mustard (*Brassica juncea* (L.) Czernj. Cosson): an overview. *International Journal of Agronomy* **13**: 1-14.

Tripathi MK, Chaturvedi S, Shukla DK and Mahapatra BS. 2010. Yield performance and quality in Indian mustard (*Brassica juncea* L.) as affected by integrated nutrient management. *Indian Journal of Agronomy* **55**(2): 138-142.

Wicks GA, Burnside OC and Felton WL. 2012. Mechanical weed management, In: *Hand Book of Weed Management Systems*. (Ed. Smith AE), Marcel Dekkers, Inc., New York, USA.

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Physico-chemical and biological properties of seed powder of flannel weed

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ABSTRACT

Assessment of various physico-chemical and biological properties of seed powder of *Sida cordifolia* was done. This plant grows along roadsides and in open land in tropical climates. Mainly useful plant parts are seeds, leaves and roots. The loose bulk density, tapped bulk density, hausner ratio and angle of repose of sample were found to be 0.31g/cm^3±0.1, 0.38 g/cm^3± 0.2, 1.22%± 1.6 and 30.96^o± 0.7, respectively. Moisture content of sample was found to be 10.00±1.6. Total ash, fat, total protein and non protein nitrogen was 3.80% ± 0.5, 10.56% ± 0.3, 22.00% ± 0.9 and 11.20% ± 0.4, respectively. Thermal stability of seeds was up to 200 ^{o}C. Low molecular weight protein bands ranging 10-60 kDa were identified. The demonstration of antimicrobial activity against microbes may be indicative of the presence of broad spectrum antimicrobial compounds. Amide I and amide II bands were two major bands of the infrared spectrum. This powder has very low water absorption capacity.

Key words: Antimicrobial activity, Infrared spectra, Physico-chemical characters, *Sida cordifolia,* Thermal stability

Sida cordifolia (bala, country mallow or flannel weed), native of India is a perennial shrub of mallow family *Malvaceae*. It has naturalized all over the world, and is considered a persistent weed in Africa, Australia and the southern United States (Pole 2006). *Sida cordifolia* grows along road sides and in open land in tropical climates of India and Sri Lanka. It is found mainly in North-Western part of India particularly Haryana, Punjab, Maharashtra and Rajasthan. It grows well in the plains of India, especially, in damp climates. The seeds contain much larger quantities of alkaloids than the leaves and roots. The weed is useful in treating colic disorders and gonorrhoea (Agharkar 1991).

Traditionally the plant has been used as CNS depressant, fat reducer, analgesics, anti-inflammatory, hypotensive, hepatoprotective and antiasthmatic (Mediros *et al.* 2005). Presence of ephedrine has highlighted the utility of this plant. Conventionally, nutrition and food companies were using plants such as *Ma-Huang* (*Ephedra* plant), because it contained relatively large amounts of ephedrine, in their weight loss products. However, since this product was banned in many countries including the USA and UK, they are now looking for alternatives. *Sida cordifolia,* with its ephedrine and pseudoephedrine has gained a set of attention and is now sold by many of these companies (Ghosal *et al.* 1975). It is almost odourless with slightly bitter taste (Rangari 2000). Some work has already been carried out using various components mostly with regard to pharmaceutical (Franco *et al.* 2005, Mediros *et al.* 2005). Not much work has been conducted in relation to various properties of this plant to use it in food formulation to treat diseases. So an attempt has been made to characterise *Sida cordifolia* for further processing. Various examinations like physical, proximate, thermal, surface, protein characterisations and antimicrobial activity are carried out.

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MATERIALS AND METHODS

Seeds of *Sida cordifolia* were collected from their natural habitat *i.e.* Mahendargarh (Southern Haryana), India and were authenticated by Department of Botany and Plant Physiology, CCS Haryana Agriculture University, Hisar, Haryana. All the chemicals used in analysis were of analytical grade supplied by HiMedia, Qualigens and central drug house. Sample prepared by crushing seeds into fine powder using mechanical blender for analysis and were stored in brown coloured glass bottles at average temperature of 25 ^{o}C.

Physical characterisation

Various physical characters like size, bulk density, angle of repose, hausner ratio and color were determined. Length and breadth of seeds were observed by using digital vernier calliper (A2583) (AOAC, 1995). For bulk density, sample powder (20 g) was taken in a 100 ml measuring graduated cylinder. The cylinder was put on horizontal surface and volume occupied by sample was recorded. Ratio of mass by volume was determined as loose bulk density. Volume was again determined after tapping the cylinder three times at an interval of 2 seconds that gives tapped bulk density (Phani *et al.* 2011). The hausner ratio (H) is a number that is correlated to the flow ability of a powder or granular material (Beddow 1995).

$$\text{Hausner ratio (H)} = \frac{\text{Tapped bulk density}}{\text{Loose bulk density}}$$

Angle of repose in general is "The angle formed between the horizontal plane and a slope line extending along the face of a heap formed by pouring material onto a horizontal surface." The height and diameter of heap of powder was noted (Lachman 1991).

tan é = h/r

The color of the powder was measured with Hunter Lab Colorimeter (Color Tec- PCM™). The color values L^*, a^*, b^* were measured directly from digital colorimeter that works on the principle of illumination. The dimension L^* means lightness, with 100 for white, 0 for black; a^* indicates redness when positive and greenness when negative, b^* indicates yellowness when positive and blueness when negative (Khouryieha and Aramounib 2012). The hue angle and chroma were calculated from a^* and b^* values, as follows:

hue angle = tan" (b^*/a^*)

chroma = "[$(a^*)^2 + (b^*)^2$]

Chemical characterisation

Moisture, ash, crude fat content of seed powder was determined by methods given in AOAC (1995). Crude protein and nitrogen was analyzed by DUMAS based protein analyzer. This procedure is faster and less complicated than Kjeldahl method (ICC 2001). Non protein nitrogen was determined by using Kjeldahl method with slight modification in preparation of sample (AACC 2000).

Surface characterisation

Surface properties were determined by using FTIR (Fourier Transform Infrared Spectroscopy) and obtained spectra was comparatively analyzed and interpreted with a chart for Characteristics IR absorption frequencies of organic functional groups and carbonyl containing functional group (Demirdroven *et al.* 2004).

Thermal analysis

Thermal analysis was carried out with the help of DSC (differential scanning colorimeter) - TGA (thermo gravimetric analysis) model (SDT Q600 V20.9). Powdered sample (4.5 g) was run in sample pan from room temperature to 400°C with slope of 10°C/min. It is a type of testing performed on samples that determine changes in weight in relation to a temperature program in a controlled atmosphere. Such analysis relies on a high degree of precision in three measurements: weight, temperature, and temperature change. Weight changes during increase in temperature were recorded. A plot of weight changes versus temperature and heat flow versus temperature was recorded (Wunderlich 1990).

Estimation of anti-microbial activity

Powdered sample was subject to aqueous extract. The resulting filtrate was then concentrated in a rotary evaporator and subsequently lyophilized to dryness. Antimicrobial activity was determined against *E.coli* and *Aspergillus heteromorphus.* Antimicrobial activity was evaluated by the bore well method. For determination of antibacterial activity bacterial cultures were inoculated on to nutrient agar. For determination of antifungal, fungal isolates of 10^6 cfu/ml were inoculated on potato dextrose agar. Well were made and impregnated with 50 µl of extract dilutions reconstituted in minimum amount of solvent at concentrations of 50, 100, 200 mg/ml were applied over each of the culture plates seeded with 0.5 McFarland and 10^6 cfu/ml cultures of bacteria and fungi respectively. Bacterial cultures were then incubated at 37°C for 18 hours while fungal culture was incubated at 30-32°C for 48 hours. Wells impregnated with 50 µl of 50, 100, 200 mg/ml of sodium benzoate (standard antimicrobial agent) were used for comparison. Antimicrobial activity was determined by measuring the zone of inhibition around each well. For each concentration three replicates were conducted against each organism (Sarangi *et al.* 2011).

Rheological analysis

Mixing behaviour of dough was determined by using Perten micro- dough LAB. The micro-dough LAB is a small scale (4g) dough mixer and analysis system to determine the quality and processing characteristics of flour and dough (Dang *et al.* 2007).

Protein characterisation

Sample was prepared by grinding 1 g sample in 1 ml chilled phosphate buffer (0.1 M, pH 7.0) along with 50 mg insoluble polyvinyl pyrrolidone. These were then centrifuged at 10,000 x g at 4 °C for 15 min. The pellet was discarded and protein in the supernatant was quantified according to Bradford (Bradford 1976). The protein extract was transferred to an equal volume of 2 x sample buffer, heated at 100° C for 3 min, cooled and used for SDS-PAGE. An aliquot containing 50 µg of sample protein was loaded in each well. Electrophoresis was carried out using vertical slab gel electrophoresis apparatus following standard method of electrophoresis (Laemmli 1970).

RESULTS AND DISCUSSION

Physical characterisation

The properties such as loose bulk density, tapped density, hausner ratio and angle of repose are often referred to as the derived properties of sample which depend mainly on size distribution, shape and tendency of the particles to adhere together. The loose bulk density, tapped bulk density, hausner ratio and angle of repose of sample were found to be 0.31g/cm^3±0.1, 0.38 g/cm^3± 0.2, 1.22%± 1.6 and 30.96^o± 0.7 respectively as shown in (Table 1). When angle of repose is less than 30°, it indicates that material is free flowing and values greater than 40° suggest a poorly flowing material. The static angle of repose value for *Sida cordifolia* seeds was found to be 30.96° indicating good flow properties. The Hausner ratio is used in a wide variety of industries as an indication of the flow ability of a powder. A Hausner ratio greater than 1.25 is considered to be an indication of poor flow ability. From the result it was seen that Hausner ratio and angle of repose was 1.22± 1.6 and 30.96^o± 0.7 respectively. It was concluded from the values that the sample has good flow properties for future application (Beddow *et al.* 1969, Conesa 2004).

Colour analysis

The colour of the material plays a major role in consumer's perception and acceptability of the product. The colour parameters L^*, a^*, b^*, hue angle and chroma for the powder (Table 2). Lower value of L^* represent darker color. Positive values of a^* and b^*indicates redness and yellowness of sample. Overall the color results indicated substantially darker and browner appearance of sample. Hue angle and chroma both relate to color perception. Hue is the attribute of color that is related to the perceived colors. Chroma represents color intensity of a surface judged in comparison to a pure white. Chroma vary from gray (chroma = 0) to brilliant red (chroma = 104). From the results it was concluded that sample was darker in color and had more color intensity (Khouryieha and Aramounib 2012).

Table 1. Physical characterisation of *Sida cordifolia* powder (put table in upper paragraph)

Characteristic	Result
Loose bulk density	0.31 g/cm^3±0.1
Tapped bulk density	0.38 g/cm^3± 0.2
Size	3.50 mm ± 0.2
Hausner ratio	1.22%± 1.6
Angle of repose	30.96^o± 0.7

Values are mean ±SD of three replicates

Table 2. Colour analysis of *Sida cordifolia* powder

Characteristic	Result
L^*	05.05±0.5
a^*	16.60±1.5
b^*	35.54±2.0
hue angle	64.95±0.4
chroma	39.23±2.0

Values are mean ±SD of three replicates

Chemical characterisation

Moisture content of sample was found to be 10.00%±1.6 .Total ash, fat, total protein and non proteinic nitrogen was 3.80% ± 0.5, 10.56% ± 0.3, 22.00% ± 0.9 and 11.20 ± 0.4 respectively. Moisture is an indicator of storage stability. Powder with high moisture content (over 14.5%) attracts mold, bacteria, and insects, all of which cause deterioration during storage. Flour with low moisture content is more stable during storage. Ash in powder can affect color, imparting a darker color to finished products. Protein content of the powder was found to be high so it can be used as a fortifying material to make protein enriched products. Results obtained were similar to that obtained by other investigators in *Hibiscus sabdariffa* plant (Adebayo-Tayo *et al.* 2000).

Surface characterisation

FTIR spectra of sample were shown in the 4000–400/cm range. The spectrum is quite complex and contains several bands arising from the contribution of different functional groups belonging to protein, lipids and carbohydrates. Amide I and amide II bands are two major bands of the protein infrared spectrum. The infrared of the protein is characterized by a set of absorption regions known as the amide region and the C–H region. The most widely used modes regions are amide ^{2}, amide ^{22} and amide ^{222}. Amide ^{2} band arises principally from C=O stretching vibration of the peptide group. Amide ^{22} band is primarily N–H bending with a contribution from C–N stretching vibrations. The amide ^{222} absorption is normally weak and arises primarily from N–H bending and C–N stretching vibrations. The amide I band (between 1600 and 1700/cm) is mainly associated with the C=O stretching vibration (70-85%) and is directly related to the backbone conformation.

Amide II results from the N-H bending vibration (40-60%) and from the C-N stretching vibration (18-40%). This band is conformationally sensitive. Amide III (1300-1400/cm) and IV (1200-1300/cm) are very complex bands resulting from a mixture of several coordinate displacements (Cakmak *et al.* 2006). The bands observed at 3700-3950/cm are due to hydroxyl

Table 3. Chemical analysis of *Sida cordifolia* powder

Characteristic	Result (%)
Moisture	10.00±1.6
Total ash	03.80±0.5
Fat	10.56±0.3
Total protein content	22.00±0.9
Non protein nitrogen Content	11.20±0.4

Values are mean ±SD of three replicates

(O-H) vibrations and band observed at 3292.49/cm is due to O-H stretching. Banding pattern observed at 3024.38/cm and 2926.01/cm are due to alkene and CH_2 asymmetric stretch mainly lipid respectively. The bands in the 1500–1200/cm regions arise mainly from the C-H bending vibrations of CH_3, CH_2 and CH functional groups. In our study these are observed at 1238.30, 1323.17, 1402.25 and 1446.61/cm. Information on phosphodiester functional groups can be obtained in the region between 1250 and 1200 cm"1 which corresponds to > P = O asymmetric stretching frequencies (Dumas and Miller 2003, Yee *et al.* 2004).

The region from 1200 to 900/cm is mainly dominated by a sequence of bands due to C-O, C-C stretching vibrations of polysaccharides. These groups mainly occur in carbohydrates and polysaccharides (Wolkers 2004). *Sida cordifolia* showed polysaccharide bands at 1064.71/cm. It can be concluded that this plant showed the presence of oligosaccharides, phosphates, proteins, carbohydrates and carotenoid. This work offers scope for further research on biological activity of this medicinal plants. In the present study, it was seen that FTIR spectroscopy can be used for easy and rapid identification of various functional groups responsible for medicinal properties.

Thermal analysis - A loss in weight up to 70 °C was observed due to presence of moisture. But after that weight was constant up to 200 °C. This indicates that the sample was stable up to 200 °C. After 200 °C, decomposition (pyrolysis oxidation) started. But in present study, weight was constant up to 200 °C that means sample used was free from impurities.

Anti-microbial activity

Results indicated that seed extract was effective against both microbes (Table 4). The highest inhibitory activity (11 mm) was noticed with the concentration of 200 mg/ml with *E. coli.* In both cases *i.e* with *E. coli* and *Aspergillus heteromorphus,* the inhibitory activity with extract was less than that of sodium benzoate at all the concentrations (50, 100 and 200 mg/ml). The inhibitory activity of seed extract was about seventy per cent of activity exhibited by standard sodium benzoate.

Table 4. Anti-microbial activity of extract of *Sida cordifolia* powder

	Zone of inhibition (mm)					
	Water extract of seeds			Sodium benzoate		
Concentration (mg/ml)	50	100	200	50	100	200
E.coli	6	8	11	9	12	15
Aspergillus hetromorphus	8	13	17	10	17	24

The demonstration of antimicrobial activity by water extract provides the scientific basis for the use of this plant in traditional treatment of disease, since most traditional medicine men use water extract as their solvent in which decoctions are prepared (Sarangi *et al.* 2011).

Rheological analysis

Results indicated that this powder has very poor mixing character as graph can reach to 250 BU (Fig. 3). Generally 500 BU is standard in case of wheat and other cereals. Therefore, it can be estimated that the powder of *S. cordifolia* alone can not be used in formulations as it has poor mixing behaviour. However it can be used to supplement with wheat powder. From the Fig.-3, following observations were made:

1 Peak resistance - The maximum torque attained, as measured from the middle curve. It was observed 229.0 mNm

2 Development time - The time taken for the dough to reach the peak resistance. It was 1.3 min.

3 Arrival time - Time required for the top curve to reach the peak resistance. It was observed 1.1 min.

4 Departure time - The required time for the top curve to fall below the peak resistance. It was observed 1.7 min.

5 Stability - The difference between the arrival and departure times. It was observed 0.6 min.

6 Mixing tolerance index - The difference between the top-curve torque at the development time and the top-curve torque at a specified time after the development time (typically 5 minutes) (Dang *et al.* 2007).

Protein characterisation - The SDS-PAGE analysis showed approximately three major protein bands, with relative molecular masses ranging from 10 to 60 kDa. In order to obtain good resolution of proteins of low molecular weight by gel electrophoresis, 10% polyacrylamide gel was used. Such a gel system gave good resolution of proteins of low molecular weight. It was seen that LMW proteins were present in sample. Effect of LMW protein was correlated with very short gap in peaks that was observed during study of mixing behaviour (Hussein 2010).

Sida cordifolia powder has good flow properties and storage stability. It was observed that the protein and fat content of powder was very high so it can be used as a fortifying material. The color intensity of powder was found high. FTIR spectra observed was quite complex and contains several bands arising from the contribution of different functional groups belonging to protein, lipids and carbohydrates. The demonstration of antimicrobial activity against microbes may be indicative of the presence of broad spectrum antimicrobial compounds. DSC-TGA thermogram was used to study thermal behaviour of powder and found that weight was constant up to 200 °C which indicate that *Sida cordifolia* was free from impurities. Rheology analysis indicared that powder has very poor mixing character but it can be easily mixed with other cereals. The SDS-PAGE analysis showed approximately three major protein bands, with relative molecular masses ranging from 10 to 60 kDa.

REFERENCES

AACC. 2000. *Approved Methods of American Association of Cereal Chemists*. American Association of Cereal Chemistry Inc., St. Paul. Minnesota.

Adebayo-Tayo BC and Samuel UA. 2000. Microbial quality and proximate composition of dried *Hibiscus sabdariffa* calyxes in Uyo, Eastern Nigeria. *Malaysian Journal of Microbiology* **5**(1): 13-18.

Agharkar P. 1991. *Medicinal Plants of Bombay Presidency*. Scientific Publishers, Jodhpur, India.

AOAC. 1995. *Official Methods of Analysis*. 15th edition. Association of Official Agricultural Chemists, Washington, DC.

Beddow JK. 1995. Professor Dr. Henry H. Hausner.1900–1995. *Advanced Powder Technology* **6**(4): 327.

Beddow JK and Grey RO. 1969. On the Hausner ratio and its relationship to some properties of metal powders. *Powder Technology* **2**(6): 323-326.

Bradford MM. 1976. A rapid and sensitive method for the quantisation of microgram quantities of protein utilizing the principle of protein-dye binding. *Analytical Biochemistry* ***72***: 248-254.

Cakmak G, Togan I and Severcan F. 2006. 17â-Estradiol induced compositional, structural and functional changes in rainbow trout liver, revealed by FTIR spectroscopy: A comparative study with nonylphenol. *Aquatic Toxicology* **77**: 53-63.

Conesa C. 2004. Characterization of flow properties of powder coatings used in the automotive industry. *Kona* **22**: 94–106.

Dang JMC, Bason ML and Booth RI. 2007. Studies of mixing characteristics and elasticity of dough using the Newport Scientific micro-dough LAB. pp.5–10. In: *Cereals 2007. Proceedings of 57th Australian Cereal Chemistry Conference*, Melbourne.

Demirdroven N, Cheatum H, Chung S, Kalil M, Knoester J and Tokmakoff A. 2004. Two dimensional infrared spectroscopy of anti parallel beta-sheet secondary structure, *Journal of the American Chemical Society* **126** (25): 81.

Dumas P and Miller L. 2003. The use of synchrotron infrared micro spectroscopy in biological and biomedical investigations. *Vibrational Spectroscopy* **32**: 3-21.

Franco CIF, Morais, LCSL, Quintans-Junior LJ, Almeida RN and Antoniolli AR. 2005. CNS pharmacological effects of the hydroalcoholic extract of *Sida cordifolia* L. leaves. *Journal of Ethnopharmacology* **98**: 275-79.

Ghosal S, Chauhan RRPS and Mehta R. 1975. Alkaloids of *Sida cordifolia*. *Phytotherapy Research* **14**: 830–832.

Hussein RM, Shahein YE, Hakim AE and Awad HM. 2010. Biochemical and molecular characterisation of three coloured types of roselle (*Hibiscus sabdariffa*). *The Journal of American Science* **11**(6): 726-732.

ICC Standard Methods No. 167. 2001. *Standard methods of International Association of Cereal Science and Technology*, International Association for Cereal Science and Technology.

Khouryieha H and Aramounib F. 2012. Physical and sensory characteristics of cookie prepared with flaxseed flour. *Journal of Science of Food and Agriculture* 12: 145-151.

Lachman L, Lieberman HA and Kaing JL. 1991. *The Theory and Practice of Industrial Pharmacy*. CBS Publication. New Delhi, 902p.

Laemmli UK. 1970. Cleavage of structural proteins during the assembly of the head of bacteriophage T4. *Nature* **227**: 680-685.

Mediros IA, Santos MRV, Nascimento NMS and Duarte JC. 2005. Cardiovascular effects of *Sida cordifolia* leave extract in rats. *Fitoterapia* 54-57.

Phani KGK, Gangarao B, Kotha NS and Lova R. 2011. Isolation and evaluation of tamarind seed polysaccharide being used as a polymer in pharmaceutical dosage forms. *Research Journal of Pharmaceutical, Biological and Chemical Sciences* **2**(2): 274-290.

Pole S. 2006. *Ayurvedic medicine*. Elsevier Health Sciences.137p.

Rangari VD. 2000. *Pharmacognosy and Phytochemistry*. Part II. 350 p.

Sarangi RR, Mishra US, Panda SK and Behra S. 2001. Evaluation of antidiarrhoeal activity of *Sida rhombifolia* L. root. *International Research Journal* of *Pharmacy* **2**(9): 157-160.

Wolkers WF, Oliver AE, Tablin F and Crowe JH. 2004. A fourier transform infrared spectroscopy study of sugar glasses. *Carbohydrate Research* **339**: 1077-1085.

Wunderlich B. 1990. *Thermal Analysis*. New York: Academic Press: 450 p.

Yee N, Benning LG, Phoenix VR and Ferris FG. 2004. Characterization of metal-Cyanobacteria sorption reactions: A combined macroscopic and infrared spectroscopic investigation. *Environmental Science* & *Technology* **38**: 775-782.

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Weed management in transplanted chilli

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ABSTRACT

An experiment was conducted at Nadia, West Bengal during 2012 and 2013 to evaluate the effect of herbicides for weed control in transplanted chilli. The weed density, dry weed biomass, WCE and yield components of chillies such as number of fruits/plant, fruit length and economic yield were significantly affected in response to weed control treatments. Treatment receiving oxyfluorfen recorded lower weed biomass (6.01 and 17.57 g/m^2) and higher WCE (81.7% and 75.0%) at 30 and 60 DAT, while hand weeding recorded the lowest weed biomass (4.87 and 17.32 g/m^2) and highest WCE (85.5 and 75.4%). Hand weeding resulted in the highest number of fruits/plant (36.11), fruit length (6.75 cm) and yield of chilli (3.46 t/ha).

Key words: Chilli, Hand weeding, Herbicide, Weeds, Weed control efficiency, Yield

Chilli (*Capsicum annuum* L.) is cultivated worldwide. It is an indispensable spice essentially used in every Indian cuisine, due to its pungency, taste, colour and aroma. Chilli fruits are rich sources of vitamin C, A and E. Immediately after transplanting, chilli seedlings grow slowly whereas weeds emerge fast and grow rapidly competing with the crop severally for growth resources, *viz*. nutrients, moisture, sunlight and space during entire vegetative and early reproductive stages of chilli (Isik *et al.* 2009). Further, wide space provided to the chilli allows fast growth of variety of weed species causing a considerable reduction in yield by affecting the growth and yield components. Presence of weeds reduces the photosynthetic efficiency, dry matter production and its distribution to economical parts and there by reduces sink capacity of crop resulting in poor fruit yield. Thus, the extent of reduction in fruit yield of chilli has been reported to be in the range of 60-70% depending on the intensity and persistence of weed density in standing crop (Khan *et al*. 2012). The choice of any weed control measures therefore, depends largely on its effectiveness and economics. Because of increased cost and non-availability of manual labour for hand weeding, herbicides not only control the weeds timely and effectively but also offer a great scope for minimizing the cost of weed control irrespective of situation. Use of pre-emergence herbicides make the weed control more acceptable to farmers, which will not change the existing agronomic practices but will allow for complete control of weeds. Hence, a study on evaluation of herbicides for weed control in transplanted chilli was planned to ascertain the effect of different herbicides on weed control and growth and yield of chilli.

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MATERIALS AND METHODS

The experiment was conducted during two consecutive *Kharif* season of 2012 and 2013 at Horticultural Farm (22°93'E, 88°53'N and 9.75 m altitude) of Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal. The experimental soil was well drained, alluvial in nature and sandy loam in texture, having pH 6.92. The experiment encompassed five treatments consisting of pendimethalin 990 g/ha, oxyfluorfen 200 g/ha, propaquizafop 75 g/ha, hand weeding and weedy check. The experiment was laid out in a randomized block design having four replications. Chilli variety "*Kajari*" was transplanted after 30 days with row to row and plant to plant distances of 50 and 50 cm, respectively. For fertilizers, the urea was used as a source of nitrogen and DAP was used as P source. N was applied in two splits (half at transplanting time and half after 30 days of transplanting) at the rate of 120 kg/ha. Data were recorded on weeds density, dry weeds biomass, weed control efficiency were recorded at 30, 60 DAT. Fruit length, fruits/plant and yield were measured at the time of harvest. Data were subjected to square root transformation $(\sqrt{x+0.5})$ and were subjected to statistical analysis by analysis of variance method. The correlation studies were made to reveal the association among the variables in the investigation (Gomez and Gomez 1984). As the error mean squares of the individual experiments were homogenous, combined analysis over the years were done through unweighted analysis.

RESULTS AND DISCUSSION

Effect on weeds

The weed control treatments significantly affected weed density/m^2 (Table 1). Higher weeds population was observed in weedy check plots (43.34 and 89.29 weeds/m^2 at 30 and 60 DAT, respectively) whereas hand weeding treatments resulted in lower weed population (7.64 and 10.21/m^2 at 30 and 60 DAT, respectively) followed by oxyfluorfen (8.81 and 14.80/m^2 at 30 and 60 DAT, respectively), pendimethalin (11.32 and 24.55) and propaquizafop (13.14 and 17.57). The higher weeds density in weedy check plots may be attributed to the open soil surface and niches available to weeds for free and aggressive growth. Timely weeding in hand weeded plots might be the possible reason for lower weeds population in these plots. These results are also in accordance with those of Adhikary and Ghosh (2014). Kumar *et al.* (2013) who also found highest number of weeds/m^2 in weedy check plots and lowest in hand weeded treatments.

Weeds dry biomass was significantly reduced by hand weeding and oxyfluorfen treatment (Table 1). Highest dry weed biomass (32.88 and 70.32 g/m^2 at 30 and 60 DAT, respectively) was recorded in weedy check plots whereas lowest dry weed biomass (4.78 and 17.32 g/m^2 at 30 and 60 DAT, respectively) were recorded in hand weeded treatments followed by oxyfluorfen (6.01 and 17.57 g/m^2). Timely eradication of weeds in hand weeding plots could be the possible reason for lower weeds fresh biomass in theses plots (Adhikary *et al.* 2014). Similarly, the inhibition effect of herbicides might have inhibited the weed seeds germination which at the end of the day resulted in less dry weed biomass. Weeds were also effectively controlled in pendimethalin and propaquizafop treated plots. Singh *et al.* (2009) and Rahman *et al.* (2012) also reported that hand weeding is the most effective weed control method. Weed control efficiency (%) differed significantly due to herbicides. At 30 DAT, hand weeding recorded higher weed control efficiency (85.5%), followed by oxyfluorfen 200 g/ha (81.7%). Pendimethalin 990 g/ha (74.7%) and propaquizafop 75 g/ha (74.4%) treatments were next in order. At 60 DAT, hand weeding recorded higher weed control efficiency (75.4%). All the herbicides were next to hand weeding. Moreover, Gul *et al.* (2011) and Shinde *et al.* (2012) revealed that weed dry biomass was significantly lower in hand weeding plots and the herbicide treated plots recorded significantly lower weed dry weight at all growth stages and at harvest compared to unweeded check which was mainly attributed to lower weed population, lower weed dry weight and higher weed control efficiency.

Effect on crop

The number of fruits/ plant were significantly affected by weed control methods (Table 2). The means analyses showed that higher number of fruits/ plant (36.11) was recorded in hand weeding plots, followed by oxyfluorfen treated plot (30.32) and minimum (16.58) was recorded from control plots in which there were no weeding done. The decrease in the number of fruits/plant in weedy check plots might be due to the increased competition for moisture, light and nutrients. Furthermore, the decrease in fruits/plant was proportional to duration of weeds competition. Higher fruits/plant in weed control plots than weedy check might be due to better growth and development of chilli plants and availability of more resources which resulted in more fruit production in chilli plant.

Different weeds control methods caused significant variation in fruit length of chilli. Higher fruit length (6.75 cm) was recorded from hand weeded plots which was followed by oxyfluorfen treated plots (5.89 cm) while minimum (4.54 cm) was recorded from weedy check plots (Table 2). Same results were obtained by Singh *et al.* (2011) who reported increase in fruit length of chillies due to weed control measures.

Table 1. Weed density, dry matter and weed control efficiency as affected by different treatments (pooled data of two seasons)

Treatment	Weed density (no./m^2)		Weed dry biomass (g/m^2)		WCE (%)	
	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT
Pendimethalin 30 EC 990 g/ha	3.37 (11.32)	4.96 (24.55)	2.89 (8.32)	4.57 (20.88)	74.7	70.3
Oxyfluorfen 23.5 EC 200 g/ha	2.97 (8.81)	3.85 (14.80)	2.46 (6.01)	4.19 (17.57)	81.7	75.0
Propaquizafop 10 EC 75 g/ha	3.63 (13.14)	4.19 (17.57)	2.91 (8.42)	4.69 (22.01)	74.4	68.7
Hand weeding	2.77 (7.64)	3.20 (10.21)	2.19 (4.78)	4.16 (17.32)	85.5	75.4
Weedy check	6.58 (43.34)	9.45 (89.29)	5.73 (32.88)	8.38 (70.32)	-	-
LSD (P=0.05)	0.16	0.26	0.15	0.24	-	-

Values given in the parentheses are the original means; Data subjected to square root transformation

Table 2. Yield attributes and yield of chilli as affected by different weed control treatments (pooled data of two seasons)

Treatment	No. of fruits/plant	Fruit length (cm)	Fruit weight/plant (g)	Fruit yield (t/ha)	Weed index
Pendimethalin 30 EC 990 g/ha	27.4	5.4	61.7	2.47	28.6
Oxyfluorfen 23.5 EC 200 g/ha	30.3	5.9	71.6	2.86	17.3
Propaquizafop 10 EC 75 g/ha	25.4	5.2	55.6	2.23	35.5
Hand weeding	36.1	6.7	86.4	3.46	0.00
Weedy check	16.6	4.5	45.6	1.83	47.1
LSD (P=0.05)	6.34	0.3	3.77	0.15	-

Hand weeding registered significantly higher fruit weight (86.39 g/plant) than rest of the treatments. Significant reduction in fruit weight per plant was in order of herbicides, *viz.* oxyfluorfen 200 g/ha (71.57 g) > pendimethalin 990 g/ha (61.68 g) > propaquizafop 75 g/ha (55.64). Weedy check recorded significantly lowest fruit weight/plant (45.63 g). Rajkumara (2009) found similar results on fruit weight of chilli against different control measures.

Fruit yield was significantly affected by different weeds control methods (Table 2). Hand weeding resulted in highest yield (3.46 t/ha) which was followed by oxyfluorfen 200 g/ha (2.86 t/ha) while minimum (1.83 t/ha) was recorded from weedy check plots. Less competition for nutrients and other available resources in hand weeding plots resulted in higher yield of chilli in these plots. Adhikary *et al.* (2014) found that yield increase may be attributed to more favorable soil moisture and nutrient utilization.

Significant differences were observed in weed index due to various weed control treatments (Table 2). Oxyfluorfen 200 g/ha showed its superiority among the herbicides and recorded significantly lower weed index (17.34) than other herbicides tried. Pendimethalin 990 g/ha (28.61) was next best treatment. Propaquizafop 75 g/ha (35.54) was intermediate. The weedy check recorded significantly higher weed index (47.12). These results are of agreement with Khan *et al.* (2012).

Hand weeding was the most effective weed control method in enhancing the growth and yield parameters of chilli. The weed density, weed biomass were drastically reduced as compared to weedy check. Similarly, the number of fruits/plant, fruit length and yield of chilli were also the highest in hand weeding. But hand weeding is time consuming, expensive and tedious though much effective. Hence, chemical weed control appears to hold a great promise for effective, timely and economic weed suppression.

REFERENCES

Adhikary P, Patra PS and Ghosh RK. 2014. Efficacy of plant extracts as bioherbicide on weeds in soybean ecosystem. *Green Farming* **5**(3): 486-488.

Adhikary P and Ghosh RK. 2014. Integrated weed management strategies in blackgram–brinjal–mustard cropping sequence. *Environment and Ecology* **32**(2A): 720-727.

Gomez KA and Gomez AA. 1984. *Statistical Procedures for Agricultural Research*, 2nd edn. Singapore: John Wiley & Sons.

Gul B, Marwat KB, Saeed Z and Hussain M. 2011. Impact of tillage, plant population and mulches on weed management and grain yield of maize. *Pakistan Journal of Botany* **43**(3): 1603-1606.

Isik D, Kaya E, Ngouajio M and Mennan H. 2009. Weed suppression in organic pepper (*Capsicum annuum* L.) with winter cover crops. *Crop Protection* **28**: 356-363.

Khan A, Muhammad S, Hussain Z and Khattak AM. 2012. Effect of different weed control methods on weeds and yield of chillies (*Capsicum annuum* L.). *Pakistan Journal of Weed Science Research* **18**(1): 71-78.

Kumar S, Rana SS, Chander N and Sharma N. 2013. Integrated weed management in garlic. *Indian Journal of Weed Science* **45**(2): 126-130.

Rahman UH, Khattak AM, Sadiq M, Ullah K, Javeria S and Ullah I. 2012. Influence of different weed management practices on yield of garlic crop. *Sarhad Journal of Agriculture* **28**(2): 213-218.

Rajkumara S. 2009. *Weed management in onion-chilli cotton relay intercropping in rainfed vertisols. Ph.D. Thesis,* University of Agricultural Science, Dharwad.

Shinde KG, Bhalekar MN and Patil BT. 2012. Weed management in rainy season onion. *Indian Journal of Weed Science* **44**(4): 264-266.

Singh B, Bhullar MS, Walia US and Randhawa SK. 2009. Effect of herbicides on weed control yield, quality and herbicide residue in radish. *Indian Journal of Weed Science* **41**(1&2): 46-48.

Singh U, Hiremath SM, Halikatti SI, Shashidhara GB and Patil PL. 2011. Evaluation of herbicides for weed control in rainfed transplanted chilli (*Capsicum annuum* L.). *Karnataka Journal of Agricultural Science* **24**(2): 125-128.

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Increase in growth and yield of pigeonpea with weed management

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ABSTRACT

A field experiment was carried out to study the effect of pendimethalin, imazethapyr and paraquat on plant growth and seed yield of pigeonpea. It was found that maximum increase in seed yield and B:C were obtained with pendimethalin as pre-emergence (PE) 1.0 kg/ha followed by (*fb*) paraquat 0.40 kg/ha at 8 weeks after sowing (WAS). The next best treatments were pendimethalin as PE 1.0 kg/ha *fb* paraquat 0.40 kg/ha 6 WAS, imazethapyr 0.075 kg at 20 days after sowing (DAS) *fb* paraquat 0.40 kg at 6 WAS and imazethapyr 0.075 kg at 20 DAS *fb* paraquat 0.40 kg at 8 WAS. Similar trend accrued with the economic returns, but B:C was highest in pendimethalin as pre-emergence 1.0 kg/ha *fb* paraquat 0.40 kg/ha at 8 WAS (2.50) followed by imazethapyr 0.075 kg/ha *fb* paraquat at 6 WAS (2.25) and 8 WAS (2.25) and pendimehalin as PE 1.0 kg/ha *fb* paraquat 6 WAS (2.20).

Key words: Paraquat, Pendimethalin, Pigeonpea, Imazethapyr

Yield loss due to weed competition in pigeonpea to the tune of 32-65% (Vaishya and Khan 1989, Kundra and Brar 1990). Slow growth habit of pigeonpea at initial stage encourages rapid growth of weeds and leads to severe crop-weed competition which finally reduces the crop yield. The traditional methods of weed control, *viz*. inter-cultivation or hand weeding is laborious, expensive and insufficient. Moreover, complete weeding during critical crop growth stages is not possible due to increasing cost and scarcity of human labour. In addition, continuous rains during early crop growth stages in the transitional tract hinder the cultural methods of weed control. Herbicides like fluchloralin as pre-plant-incorporation (PPI) and pendimethalin as pre-emergence (PE) have been recommended for weed control, however, these are effective only during initial period (up to 30 DAS). Thus, for the effective control of weeds throughout the crop season, use of post-emergence herbicides has been found safe and effective in crops with 100-110 days maturity. It is also observed that use of single post-emergence herbicides at 15-20 DAS may effectively control the weeds during initial growth period but could not during entire critical growth period (60-70 days) in mid-late pigeonpea cultivars.

Certain weed flora emerge late in the season among broad-leaved weeds like *Alternanthera triandra* that escape from early post-emergence herbicides. This warrants the use of early post-emergence herbicides followed by non-selective herbicides like paraquat at 40 or 60 DAS for weed control to widen the weed-control spectrum, including grasses and broad-leaved weeds and their phytotoxicity, if any, to the crop. Paraquat is cationic herbicides with zero persistence in soils. They desiccate green portions of the plants quickly. Legume did not respond to paraquat. Dalton (1992) reported substantial increases in the nodular glutathione content of the paraquat treated, 25-28 days old soybean plants. Paraquat is more phytotoxic to plants with low glutathione reductase (GR) activity than those with high GR. Potato, tobacco, sugarcane, cotton and pigeonpea has more GR activity. Under such circumstances, herbicides in combination with cultural practices offer economically suitable and effective control of weeds. Keeping these points in view, the present study was undertaken to know the effect of weed management practices on weed control efficiency, morpho-physiological, and yield in pigeonpea.

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MATERIALS AND METHODS

A field experiment to study the effect of post-emergence herbicides, *viz*. pendimethalin, imazethapyr, quizalofop-ethyl and paraquat on growth and yield of pigeonpea cultivar '*PKV TARA*' was carried out at Pulses Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during 2011-12 to 2012-13. The soil of experimental site is clayey with pH 8.0, having available N 200 kg/ha, available P 19.0 kg/ha, available K 340 kg/ha and organic C 4.0 g/kg. The experiment was laid out in randomized complete block design having three replications. The treatment comprised of weedy (without removal of weeds), weed-free (weeding done as on appearance of weeds to keep the plot free of weeds), hand weeding twice at 25 and 50 DAS and pendimethalin as pre-emergence and, post-emergence application of imazethapyr at 20 days after sowing (DAS) followed by non-selective herbicides paraquat at 6 and 8 weeks after sowing (WAS) with knapsack sprayer fitted with a flat-fan nozzle using 500 liters water/ha. Data on weed density and dry weight of weeds were recorded at 60 DAS and at harvest using quadrate 1 x 1 m. The N (25 kg/ha) through urea and P (50 kg/ha) through diammonium phosphate were applied as basal.

Yield attributes and seed yield of pigeonpea were recorded at the time of harvest. The economic analysis of each treatment was done on the basis of prevailing market rates of the inputs used and out-puts (excluding stover) obtained under each treatment. The crop was sown on 29 June 2010 and 6 July 2011 was harvested on 25 December 2010 and 20 December 2011 respectively. The total rainfall received during the crop growth was 1006.5 mm in 43 rainy days during 2010 and 464.3 mm in 34 rainy days during 2011. The required plant population (90 cm row to row and 20 cm plant to plant) was maintained by thinning plants after three weeks of sowing.

RESULTS AND DISCUSSION

Effect of weeds

The weed flora emerged during the period of experimentation were: grasses like *Cynodon dactylon* (L.) and *Bracharia* sp. (L.); sedges like *Cyperus rotundus* (L.) and broad-leaved weeds like *Alternathera triandra* (L.), *Acalypha indica* (L.), *Digeria arvensis* (L.), *Amaranthus viridis* (L.), *Phyllanthus niruri* (L.), *Cyanotis axillaris* (L.), *Commelina benghalensis* (L.), *Parthenium hysterophorus* (L.). Grasses and sedges especially *C. rotundus* appeared during the initial growth stages, whereas broad-leaved weeds especially *A. triandra* emerged late so it escape from the post-emergence herbicides spray. These weeds emerged during 15 to 20 DAS, thereafter up to continuously throughout the growth stages. The result revealed that among the herbicides, combination of imazethapyr at 20 DAS *fb* paraquat at 6 WAS or 8 WAS and pendimethalin *fb* paraquat at 6 WAS or 8 WAS recorded the lowest dry weight of weeds at all the growth stages. In the first year, weed dry matter and yield were higher than in others, which could be due to good quantum of rainfall received. Singh *et al.* (2002) also reported higher weed infestation in pigeonpea in a highly rainfall year. Imazethapyr did not provide satisfactory weed control of *A. indica* in pigeonpea fields.

Effect on crop

The highest yield attributes, *viz.* branches/plant, pods/plant, grain weight/plant and 100-grain weight were recorded in season long weed free plots mainly due to lowest dry weight of weeds (Table 2). The lowest numbers of pods were obtained from plots where the crop was kept weedy throughout the growing period and it was due to severe weed competition for resources, nutrients, moisture, light and space (Bhalla *et al.* 1998). The development of grain reflects the photosynthetic potential of a crop plant and its capacity to transport it assimilates to economically valuable plant organs. On the basis of pooled data statistically equivalent yield was recorded with pendimethalin as PE *fb* paraquat at 8 WAS closely followed by

Table 1. Weed dry matter, yield and economics of pigeonpea as influenced by different treatments

Treatment	Dry matter of weed (g/m^2)				Seed yield (t/ha)			Total cost (x10^3 `/ha)	NMR (x10^3 `/ha)	B:C
	2010-11		2011-12							
	60 DAS	At harvest	60 DAS	At harvest	2010-11	2011-12	Pooled			
HW twice at 25 and 50 DAS	20.4	12.0	17.19	1.90	1.48	1.23	1.36	16.89	30.67	1.82
PM 1.0 kg as PE *fb* HW at 50 DAS	24.6	13.1	17.08	0.85	1.17	1.24	1.21	18.70	23.55	1.26
IM 0.075 kg at 20 DAS *fb* 1HW at 50 DAS	23.2	13.0	10.26	1.04	1.47	1.23	1.35	16.68	30.62	1.84
PM 1.0 kg as PE *fb* PQ 0.40 kg at 6 WAS	15.20	5.75	10.20	0.97	1.45	1.43	1.44	15.75	34.63	2.20
IM 0.075 kg at 20 DAS *fb* PQ 0.40 kg at 6 WAS	18.31	4.99	13.31	0.99	1.49	1.30	140	15.05	33.90	2.25
PM 1.0 kg/ha *fb* PQ 0.40 kg at 8 WAS	14.31	5.95	10.31	0.88	1.56	1.39	1.48	14.77	36.88	2.50
IM 0.075 kg at 20 DAS *fb* PQ 0.40 kg at 8 WAS	18.28	6.05	12.28	0.80	1.50	1.26	1.38	14.91	33.48	2.25
Weedy check	58.91	45.2	24.56	12.86	1.50	0.86	1.18	9.94	31.41	3.16
Weed free	00	00	00	00	1.01	1.53	1.27	21.39	23.02	1.08
LSD (P=0.05)	-	-	-	-	0.13	0.13	0.07	-	5.17	-

IM-Imazethapyr; PM-Pendimethalin; PQ-Paraquat; Selling price: Seed yield-35/kg

Table 2. Yield attributes of pigeonpea as influenced by different treatments (mean of two years)

Treatment	Plant height (cm)	No. of bran ches/plant	No. of pods/ plant	Seed weight/ plant (g)	100 seed weight (g)
HW twice at 25 and 50 DAS	162	18.4	126	26.6	10.65
Pendimethalin 1.0 kg as PE *fb* HW at 50 DAS	164	18.6	128	27.1	10.59
Imazethapyr 0.075 kg at 20 DAS *fb* 1HW at 50 DAS	166	17.8	110	22.6	10.39
Pendimethalin 1.0 kg as PE *fb* paraquat 0.40 kg at 6 WAS	163	18.2	119	23.6	10.15
Imazethapyr 0.075 kg at 20 DAS *fb* paraquat 0.40 kg at 6 WAS	164	19.8	133	28.4	10.33
Pendimethalin 1.0 kg/ha *fb* paraquat 0.40 kg at 8 WAS	167	19.3	131	27.6	10.49
Imazethapyr 0.075 kg at 20 DAS *fb* paraquat 0.40 kg at 8 WAS	166	18.9	130	28.4	10.29
Weedy check	183	16.7	86	17.4	9.77
Weed free	156	23.9	135	27.7	10.34
LSD (P=0.05)	151	0.3	89	3.8	0.02

pendimethalin as PE *fb* paraquat at 6 WAS, imazethapyr at 20 DAS *fb* paraquat at 6 WAS and imazethapyr at 20 DAS *fb* paraquat at 8 WAS, respectively. Similar result was obtained by Khanna (2012). This might be due to lowest dry matter of weeds without causing any crop phytotoxicity. Highest yield levels was recorded during first year of investigation due to onset of good quantum of post-monsoon rains during terminal growth period; hence crop growth was good and the experimental results largely influenced by this. The magnitude of herbicide effects varied significantly with season, indicating that environmental parameters play a key role in determining the extent of herbicide damage. Soil moisture availability appears to be a key factor influencing plant health, herbicide uptake and metabolism, nodulation, N_2 fixation, and ultimately the ability of the plant to recover from a stress such as a herbicide application. Herbicide absorption and translocation to the site of action in plants varies with environmental factors and crop health and is difficult to predict (Devine *et al.* 1993, Green and Strek 2001).

Economics

Among the different weed management practices, pre-emergence application of pendimethalin 1.0 kg/ha *fb* paraquat 0.40 kg/ha at 8 WAS recorded higher gross and net returns (Table 1). The next best treatments were pendimethalin 1.0 kg/ha as PE *fb* paraquat 0.40 kg/ha at 6 WAS, imazethapyr at 20 DAS *fb* paraquat at 6 WAS and imazethapyr at 20 DAS *fb* paraquat at 8 WAS. The lower net returns and benefit : cost (1.26) with pre-emergence application of pendimethalin 1.0 kg/ha *fb* HW at 50 DAS might be owing to higher cost incurred in hand weeding.

It may be concluded that a practice that involves a pre-emergence application of pendimethalin 1.0 kg/ha and paraquat at 6 or 8 WAS could be an effective options for controlling weeds as well as for getting higher yield of pigeonpea.

REFERENCES

Bhalla CS, Kurchania SP and Paradkar NR. 1998. Herbicidal weed control in chickpea (*Cicer arietinum* L.). *World Weeds* **5**(1-2): 121-124.

Dalton DA. 1992. Effects of paraquat on the oxygen free radical biology of soybean root nodules *Bulletin of Environmental Contamination and Toxicology* **45**(5): 721-726.

Devine MD, Duke SO and Fedtke C. 1993. *Physiology of herbicide action*. Prentice-Hall Inc.: Englewood Cliffs, NJ: 441 p.

Green JM and Strek HJ. 2001. Influence of weather on the performance of acetolactate synthase inhibiting herbicides, pp. 505–512. In: *Proceedings of International Conference*. Brighton, UK, 12-15 November 2001. (British Crop Protection Council:Farnham, UK).

Kundra HC and Brar LS. 1990. Integrated weed management in pigeonpea *(Cajanus cajan)*, p. 83. In: *Proceedings of Biennial Conference of Indian Society of Weed Science*, Jabalapur.

Singh VK, Singh NP, Sharma B and Sahu JP. 2002. Economic viability of different planting and weed control methods in pigeon pea in Tarai regions of Uttaranchal. *Indian Journal Pulses Research* **15**(2): 186-187.

Vaishy RD and Khan AM. 1989. Weed management with herbicides in pigeonpea. *International Pigeonpea Newsletter* **9**: 14-16.

Khanna V, Guriqbal Singh, Poonam Sharma and Harpreet Kaur. 2012. Influence of herbicides on *Rhizobium* growth and its symbiosis with pigeonpea. *Trends in Biosciences* **5**(2): 133-135.

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Bioefficacy of halosulfuron-methyl against sedges in bottle gourd

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ABSTRACT

A field experiment was conducted at Bhubaneswar to evaluate the efficacy of halosulfuron-methyl for the control of weeds in bottle gourd. The treatments constituted of new herbicide formulation halosulfuron-methyl (75% WG) in different doses (52.5, 67.5, and 135 g/ha) at 3-4 leaf stages of *Cyperus rotundus* compared with recommended dose of metribuzin at 490 g/ha and two hand weeding on 20 and 40 DAS with unweeded control. The results revealed that the density of *Cyperus rotundus* was distinctly controlled by application of halosulfuron-methyl. But grasses and broad-leaved weeds were considerably lower in pre-emergence application of metribuzin at 490 g/ha. The lowest total weed dry weight, higher weed control efficiency and cane yield were recorded in metribuzin 490 g/ha followed by halosulfuron-methyl 135 g/ha. The herbicide tested in this study did not show any residual phytotoxic effect on succeeding crop of cowpea.

Key words: Bottle gourd, Halosulfuron-methyl, Chemical control, Sedges

Botttle gourd (*Langenaria siceraria* (Mol.) Standl) is a commonly grown vegetable of India and belongs to family Cucurbitacea. It is cultivated in the 0.11million ha area with a production and productivity of 1.43 million tones and 13.2 t/ha, respectively (Anonymous 2011). Besides, many reason for its low productivity, poor management of weed is the one of them. Due to slower early growth and close canopy structure, the bottle gourd faces severe competition from weeds, particularly the perennial sedges resulting in huge yield loss. The loss in fruit yield of bottle gourd due to weeds was estimated to be up to 40% (DWSR 2013). Halosulfuron-methyl is known to be very effective against sedges (Rathika *et al.* 2013). However, no information is available on testing of the newer herbicides on the bottle gourd in the state of Odisha; hence the present investigation was carried out.

MATERIALS AND METHODS

Field experiment were conducted at the Central Farm of OUAT, Bhubaneswar during the *Kharif* season of 2012 and 2013 to evaluate the bioefficacy of halosulfuron-methyl against sedges especially *Cyperus rotundus* L. Six different treatments consisting of three different doses of halosulfuron-methyl *i.e* 52.5, 67.5 and 135 g/ha and one conventional herbicide *i.e* pre-emergence application of metribuzin 490 g/ha along with two hand weeding *i.e* 20 and 40 DAS and one untreated control were evaluated in a randomized block design with four replications. The soil of the experimental site was sandy clay loam in texture, neutral in soil reaction (pH7.4), low in organic carbon C (0.41%) and available N (192 kg/ha),medium in available P (12.8 kg/ha) and K(235 kg/ha). The bottle gourd variety "*Devagiri*" was sown in three seeds/pit where the pit size was (20×20×20 cm) on 25 June 2011 and 30 June 2012. All the standard packages of practices with pro-phylactic measure against insect pests were followed. The herbicide halosulfuron-methyl was applied at 3-4 leaf stage of the *Cyperus rotundus* L. and the metribuzin was applied 2 days after sowing of the crop. Herbicides were sprayed with knapsack sprayer fitted with flat fan nozzle with water as a carrier at 500 litres/ha. Data on weed density and total weed dry weight at 30 and 45 DAS were recorded by adopting standard procedure of 0.25 m^2 quadrate. Weed control efficiency was calculated using the accepted formula and expressed in percentage. The yield of crop and economics were also recorded for observation.

RESULTS AND DISCUSSION

The crop was mainly infested with the sedges (21%) along with grasses (53%) and broad- leaved weeds (26%). The predominant grasses were *Cynodon dactylon* and *Digitaria sanguinalis.* Weeds like *Chenopodium album, Melilotus indica, Ludwiga parviflora, Celosia argentia, Coronopus didymus* were dominant among broad-leaved weeds and *Cyperus rotundus* among sedges. The application of halosulfuron-methyl completely controlled the sedges particularly the *Cyperus rotundus* population and dry

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matter irrespective of doses followed by the metribuzin treated plots where the population were 14/m^2 and 6.8 g/m^2 in 1st year and 17/m^2 and 7.1 g/m^2 in 2nd year respectively (Table 1). However the lowest total weed population (21/m^2 and 25/m^2) were observed in case of two hand weeding at 20 and 40 DAS followed by the application of metribuzin in both the years. The significantly lowest weed dry weight (21.52 g/m^2 and 22.63 g/m^2) was also recorded in this treatment in comparison to all other treatments. It is evident that the grasses and other broad leaved weeds are effectively controlled by the metribuzin treatments whereas the halosulfuron-methyl effectively controlled the sedge population *i.e. Cyperus rotundus*. The result was in conformity with the findings of Rathika *et al*. (2013) and Meher *et al*. (2013).

The highest fruit yield of (22.8 and 23.6 t/ha) was recorded with two hand weeding followed by metribuzin treatments and the lowest (14.3 and 13.9 t/ha) was obtained in unweeded check (Table 2). Among different doses of halosulfuron-methyl, the application 52.5 g/ha recorded 48 and 67% of yield advantage over unweeded control in both the years, respectively and it was at par with the higher dose of 67.5 g/ha. The higher dose of 135 g/ha significantly reduced the yield in comparison to other two lower doses. The variation in fruit yield in different treatments was due to different weed density and nature of weed flora. The effective weed control at the initial stage of crop weed competition resulted into higher yield in case of two hand weeding followed by the pre- emergence application of metribuzin. Lower fruit yield was obtained in unweeded control. These results were in conformity to the findings of Vyas and Jain (2003).

The herbicidal treatments brought about lower cost of cultivation as compared to two hand weeding (14.52×10^3 and 14.98×10^3 `/ha). The highest B:C ratio of 2.63 and 2.59 was observed in halosulfuron-methyl 52.5 g/ha, followed by metribuzin treated plots and lowest with unweeded check 1.19 and1.31 respectively in both the years (Table 2).

There was no phytotoxic symptoms observed in the bottle gourd crop even in higher doses of the herbicide and there was no residual effect on the succeed-

Table 1. Effect of halosulfuron-methyl on weed growth at 30 DAS in bottle gourd

Treatment	*C. rotundus* density (no/m^2)		*C. rotundus* dry matter (g/m^2)		Total weed density (no/m^2)		Total weed dry matter (g/m^2)		WCE (%)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Halosulfuron-methyl 52.5 g/ha	1	0	0.02	0	38	42	28. 21	32.94	61.2	63.2
Halosulfuron-methyl 67.5 g/ha	0	0	0	0	32	37	30. 34	34.01	58.3	62.1
Halosulfuron-methyl 135 g/ha	0	0	0	0	27	33	33.56	39.94	53.9	55.5
Metribuzin 490 g/ha	14	17	6. 8	7.1	25	31	24.18	31.34	67.1	65.0
Two hand weeding (20 and 40 DAS)	16	21	7.4	8.3	21	25	21.52	22.63	70.6	74.7
Unweeded check	37	43	13.6	14.5	89	104	72.87	89.74	-	-
LSD (P=0.05)	2.31	2.28	1.31	1.85	3.15	4.36	7. 11	9.98	-	-

WCE-Weed control efficiency, DAS-Days after sowing

Table 2. Effect of halosulfuron-methyl on yield and economics in bottle gourd and its residual effect on succeeding cowcrop

Treatment	Yield (t/ha)		Cost of cultivation ($\times 10^3$ `/ha)		B:C ratio		Seed yield of cowpea (kg/ha)	
	2012	2013	2012	2013	2012	2013	2012	2013
Halosulfuron-methyl 52.5 g/ha	21.25	23.34	13.21	13.54	2.63	2.59	742	756
Halosulfuron-methyl 67.5 g/ha	20.30	19.85	13.34	13.69	2.57	2.48	754	798
Halosulfuron-methyl 135 g/ha	18.54	20.10	13.56	13.87	2.41	2.34	712	734
Metribuzin 490 g/ha	22.64	23.56	13.18	13.09	2.60	2.58	781	812
Two hand weeding(20 and 40 DAS)	22.87	23.67	14.52	14.98	2.13	2.37	802	826
Unweeded check	14.32	13.90	12.87	12.75	1.19	1.31	721	744
LSD (P=0.05)	1.88	2.06	-		-	-	NS	NS

ing crop cowpea. However the yield of cowpea obtained in each treatments showed no significant difference among them (Table 2). The result was also similar with the findings of Punia *et al*. (2011).

Post-emergence application of halosulfuron-methyl 52.5 g/ha at 3-4 leaf stage of sedges was very effective in controlling the specific weed and thereby increase the yield and profitability of the bottle gourd.

REFERENCES

Anonymous. 2011. Current status of vegetable crops in India, pp 13. In: *Annual Progress Report*, Department of Horticulture, Bhubaneswar, Odisha

Meher C, Samar S, Dharam B, Narendra S and Vijay K. 2013. Halosulfuron-methyl: A new post- emergence herbicide in India for effective control of *Cyperus rotundus* in sugarcane and its residual effect in succeeding crops. *Sugar Technology* **15**: 214-218.

Punia SS, Singh S and Yadav D. 2011. Bioefficacy of imazethapyr and chlorimuron-ethyl in cluster bean and their residual effect on succeeding crops. *Indian Journal of Weed Science* **43**: 48-53.

Rathika S, Chinnusamy C and Ramesh T. 2013. Efficiency of halosulfuron-methyl on weed control in sugarcane. *International Journal of Agriculture, Environments and Biotechnology* **6**(4): 611-616.

Vyas MP and Jain AK. 2003. Effect of pre- and post-emergence herbicides on weed control and productivity of soybean. *Indian Journal of Agronomy* **48**(4): 309-311.

DWSR. 2013. Weed management in bottle gourd, pp-02.In: *Weed News* **13**(2), Directorate of Weed Science Research, Jabalpur.

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Additive properties of mint weed in polyfilms

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ABSTRACT

Biopolymer films have been regarded as potential replacements for synthetic petrochemical based polymers for different uses mainly in pharmaceuticals and packaging applications in view of strong awareness towards more environmental friendly materials. Polysaccharide-mucilage and lignin concentrate were isolated from the mint weed (*Hyptis suaveolens*). Potato starch was modified and starch-lignin-mucilage-polyvinyl alcohol was prepared in different composition from lignin and mucilage isolates of *H. suaveolens*. The physical properties like film appearance, opacity, swelling per cent and mechanical properties namely tensile strength and elongation per cent of polyfilms were measured. Acetylated starch with lignin isolates showed good elongation % (17.43±0.24) in comparison to native starch films (2.62±0.11). Acetylation increased the tensile strength while *Hyptis* lignin increased the elongation per cent of films. The tensile strength of mucilage and polyvinyl film blend was found to be decreased significantly. This study revealed that lignin and mucilage blends are compatible with starch and synthetic polymers which could be advantageous for cost reduction with improved properties and enhanced increase range of application.

Key words: Additive, Biopolymer films, Elongation per cent, *Hyptis suavelones*, Mucilage, Lignin

Starch has received considerable attention because of its complete biodegradable nature and low cost (Arvanitoyannis *et al.* 1994, Liu 2005, Garcýa *et al.* 2006). Starch film properties can be influenced by the addition of different additives as fillers or modified chemical reactions and can also be readily converted chemically and biologically into many useful and diverse products such as paper, textiles, adhesive, beverages, confectionaries, pharmaceuticals and plastics (Agbo *et al.* 2010). Arvanitoyannis *et al.* (1998) and Lafargue *et al.* (2007) studied formulation of composite films by mixing with other biopolymers, such as gelatin.

Hyptis suaveolens Poit, the pig nut or mint weed, a member of Lamiaceae family and native of tropical regions of Mexico, West Indies and South America, has become naturalized in tropical parts of Africa, Asia and Australia. It has also well established in India and is considered as a potent alien invader for reducing biodiversity and palatable grasses. However, *H. suaveolens* also has good medicinal value owing to the presence of essential oil, a characteristic feature to the family Lamiaceae. But, due to these essential oils, it is unpalatable to animals. It is known to be used in several traditional medicines for the treatment of various illnesses and has been found to possess significant pharmacological applications (Kuhnt *et al.* 1995). It is also a potential source of lingo-cellulosic material and mucilage which can be utilize as an additive in polymeric materials to change the properties according to their applications. Hitherto, this properties was unexplored, therefore, in the present study, we have studied the compatibility of *Hyptis* lingo-cellulosic and mucilage material with starch and polyvinyl alcohol for use in making polyfilms.

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MATERIALS AND METHODS

The study was carried out during 2011 and 2012 at Non Wood Forest Produce Lab of Tropical Forest Research Insitute, Jabalpur located at 23.1667° N, 79.9333° E. The aerial parts of the weed was collected from the forest and roadside. The material was dried in shade

Isolation of starch: Starch was isolated using a procedure of Kim *et al.* (1995). The potato tubers were peeled, cut into 5-6 cm cubes and immediately rinsed in sodium sulphate solution and then macerated at low speed in a Waring blender for two minutes. The homogenate was consecutively sieved. The white-starch sediment was washed several times with water and then centrifuged. The white-starch sediment was dried in an oven at 40^0 C for 48 h.

Modification of starch: Acetylated and hydroxypropylated products of starch were prepared by the modification according to procedure reported by Jarowenko (1986).

Extraction of lingo-cellulosic material: Aerial part of *Hyptis* was collected and leaves were removed. Dried twigs was used as the source of lignin-cellulosic material. Fifty gram material was digested in 500 ml of 1% NaOH solution for 5 hours at around 100 ^{0}C. The solution was filtered and filtrate was concentrated to 75 ml. The weight of dry extract was found to be 9 g. *i.e,* 75 ml solution had almost 3 gm of lignin.

Extraction of mucilage: Fruits or seeds of H. suaveolens were used for isolation of mucilage. Fruits were soaked in warm water for 4 h, boiled for 2 h and kept aside for 2 h for release of mucilage into water. The material was squeezed in a muslin cloth and centrifuged. Equal volume of ethyl alcohol was added to filtrate to precipitate the mucilage. The separated mucilage was dried in oven at about 45 ^{o}C and powdered. The powdered mucilage was stored in descecrator until further use (Malviya *et al.* 2010).

Preparation of starch-lignin-mucilage polymer: Starch-based films were prepared by casting technique. Polyol, glycerol was used to plastisize the films. Films were prepared using suspension of plasticizer, potato starch, distilled water, lignin and mucilage isolate. Four gram of starch was mixed with 75 ml water with constant stirring at 100 ^{0}C until the mixture turned semi-viscous. Ten ml of lignin solution was added to the semi-viscous starch solution. The starch-additive mixture was stirred vigorously for another ten minutes. Later, the polymer mixture was spread on a plastic coated plate and left to cure. Film forming suspension was heated with continuous mixing by a magnetic stirrer and at short intervals by hand with a glass rod to above 90 ^{0}C- 100 ^{0}C to obtain film forming solution. The solution was kept at 90 ^{0}C for 5 minutes before letting it cool down to 50 ^{0}C. Air bubbles formed during heating were removed from solution before casting on glass plate. Films were removed from plate after curing in an oven at 35 ^{0}C. Similarly, films of polyvinyl alcohal, modified starch and mucilage were prepared.

Film solubility in water, oil and hexane: The film solubility was determined by following procedure described by Gontard *et al.* (1992). The film pieces of 2 x 2 cm were cut from each sample and stored in a dessicator with silica gel for 7 days. Samples were weighed and placed into test beakers with 80 ml deionized water and were maintained under constant agitation at 200 rpm for 1 h at room temperature (approximately 25 ^{0}C). After soaking, the remained pieces of film were collected by filtration and dried again in an oven at 60 ^{0}C to constant weight. The percentage of total soluble matter (% solubility) was calculated as follows:

% Solubility= (Final weight- initial weight of film/ Final dry weight)x100

Film opacity: Film opacity was determined using a procedure described by Gontard *et al.* (1992). The film sample was cut into a rectangle and placed on the internal side of a spectrophotometer cell. The absorbance spectrum (400–700 nm) was recorded for each sample using spectrophotometer. Film opacity was defined as the area under the recorded curve determined by an integration procedure. The opacity was expressed as absorbance units per nanometers (AU nm).

Film appearance: Homogeneity and appearance of the films were examined by visual observation and optical microscopy.

Thickness of Films: Thickness of the films was measured with the help of micrometer.

Mechanical Testing: Mechanical properties *i.e.* tensile strength, the percentage elongation at break and young's modulus were evaluated. The 12 x 2 cm^2 sized polymeric films were cut and subjected for the mechanical analysis. The tensile strength, tensile modulus, and elongation were measured using an Instron Universal Testing machine by adopting IS 2508 method at Central Institute of Plastic Engineering, Bhopal (M.P.).

RESULTS AND DISCUSSION

The transparent, translucent, homogeneous, thin and flexible films were obtained with different blends from native and chemically modified starches.

The oven-dried lignin blended films had a pale yellow colour. No pores or cracks were detected in films prepared by filmogenic suspension containing lignin and mucilage as an additive. The thickness of the tested films varied 0.14-0.16 mm.

The film opacity and swelling in different medium are the critical properties of a film. Opacity of film in different blends and swelling in different solvents are given (Table 1). Significant variation was observed in swelling % of different blends in water and oil, used as solvent. All films were swelled in water except acetylated starch and polyvinyl blend. The swelling properties of films in oil was decreased with the addition of *Hyptis* mucilage and lignin. Transparent films were characterized by low values of the area below the absorption curve.

Table 1. Physical properties of native and chemically modified starch films with and without additives

Film composition	Swelling %			Film opacity [AU nm]
	Water	Haxane	Oil	
S+P	0.15±0,02	0.05%	0.33±0.01	100±0.00
Ac.S + P	0.05±0.01	Resistive	0.250.03±	100±0.00
Ac.S + H + P	0.66±0.02	Resistive	0.09±0.00	0.00±0.00
AcS + PVOH	0.00±0.00	Resistive	0.03±0.04	100±0.00
HPS+ H+ P	1.24±0.07	Resistive	0.12±0.03	0.00±0.00
S+mucilage + P	0.24±0.03	Resistive	0.17±0.01	0.00±0.00
PVOH + mucilage + P	1.07±0.08	Resistive	0.14±0.02	64.540.01
LSD(P=0.05)	0.35	NS	0.07	-

S-starch,Ac- acetylated, PVOH-Polyvinyl alcohol, P-plasticizer, HP-Hydroxypropylated, H-*Hyptis*

The tensile strength and elongation at break of native and modified starches and polyvinyl blended films are shown in Table 2. Results indicated that the addition of different additives caused differences in both tensile strength and elongation of polysaccharide films as well as polyvinyl alcohol.

The maximum tensile strength (427.5 kgf/cm^2) was observed in modified followed by PVOH blend (391.79 kgf/cm^2) and 10.42 mm and 1.85 mm elongation, respectively. The maximum elongation (17.43 mm) was observed in film blends with *Hyptis* lignin isolates corresponds to 159.41 kgf/cm^2 tensile strength but minimum tensile strength (92.67 kgf/cm^2). Significant difference was observed in different blends with hyptis lignin isolate and mucilage. Mucilage reduces tensile strength of polyvinyl alcohol in comparison to acetylated starch and polyvinyl films.

Baumberger *et al.* (1998), studied starch-lignin films, also found that lignin improves water resistance. Without additional plasticization, lignin increases the brittleness of both films and foams. The present results can be compared with those of Baumberger *et al.* (1998) and Stevens *et al.* (2007) prepared starch-kraft lignin pre-extruded molded films containing only water as a plasticizer found that introduction of lignin increase the hydrophobicity of starch-lignin films and reported that hydrophobic nature of films can reduce by the addition of plasticizer. They observed tensile elongations at break of 1.0-1.5%.

Table 2. Mechanical properties of films of different composition

Polymeric blends	Width (mm)	Elongation at break(mm)	Tensile strength (kgf/cm^2)
S+P	25.1	2.62±0.11	99.7±8.3
Ac.S +P	25.5	1.85±0.09	427.5±11.2
AcS+H+P	25.1	17.43±0.24	159.4±16.7
Ac.S +PVOH+ P	25.6	10.42±0.90	391.8±12.2
HPCA+ H+ P	25.5	2.73±0.23	310.3±10.1
S+mucilage+ P	25.2	14.24±1.2	105.4±8.1
PVOH + mucilage + P	25.5	6.89±0.39	57.2±9.2
LSD (P=0.05)		2.31	28.9

S-starch,Ac- acetylated, PVOH-Polyvinyl alcohol, P-plasticizer, HP-Hydroxypropylated, H-*Hyptis*

H. suaveolens is a good source of polysaccharide-mucilage. Its lignin and mucilage showed compatibility in polymeric blends.

The possible advantage of using other polymers with native starch granules lies in that it can be deformed and distributed in the blending process and enhance other ways of utilization.

Starch-based film incorporated with lignin and mucilage were compact, translucent and presented good flexibility and elastic than native starch-based films In addition they were easy to handle when dried off.

The films containing lignin possessed good mechanical. However, it affect on opacity of the films. Starch is a widely used biopolymer, but lignin-starch systems are a relatively unexplored area in biopolymer research.

The results indicate that blending of starches and polyvinyl alcohol with other polymers could be advantageous for cost reduction with improved properties when compared to native starches of species. Thus the chemical structure of the polymer was changed by blending it with other polymers to improve its physical characteristics thus widening range of application. Polymer blending offers interesting possibilities of preparing inexpensive biodegradable materials with useful mechanical properties.

REFERENCES

Agbo IU and Odo GE. 2010. The effect of hypochlorite oxidation and acetylation on some of the physico-chemical properties of *Icacina trichantha* starch; *Bio-Research* **8**(1): 593-597.

Arvanitoyannis I, Nakayama A and Aiba SI. 1998. Edible films made from hydroxypropyl starch and gelatin and plasticized by polyols and water. *Carbohydrate polymers* **36**:105-119.

Baumberger S, Lapierre C, Monties B, Della Valle G. 1998. Use of kraft lignin as filler for starch films. *Polymer Degradation and Stability*, **59**: 273-277.

Garcia MA, Martino MN, Zaritzky NE. 2000. Microstructural characterization of plasticized starch-based films. Starch/Starke **52**(4): 118-124.

Gontard N, Guilbert S and Cuq JL. 1992. Edible wheat gluten film: Influence of the main process variabels on film properties of an edible wheat gluten film. *Journal of Food Science* **58**: 206-211.

Jarowenko W. 1986. Acetylated starch and miscellaneous organic esters, pp. 55-77. In: *Modified starches: Properties and uses* (Ed. Wurzburg OB). CRC Press, Inc, Florida.

Kim YS, Wiesenborn DP, Orr PH and Grant LA. 1995. Screening potatoes starch for novel properties using differential scanning calorimetry. *Journal of Food Science* **60**:1060-1065.

Kuhnt M, Probstle A, Rimpler H, Bauer R and Heinrich M. 1995. Biological and pharmacological activities and further constituents of *Hypatis vertcillata*. *Planta Medica* **61**(3): 227-232.

Lafargue D, Pontoire B, Buléon A, Doublier JL, Lourdin D. 2007 .Structure and mechanical properties of hydroxypropylated starch films. *Biomacromolecules* **8**, 3950-3958.

Liu H, Ramsden L and Corke H. 1999. Physical properties of cross-linked and acetylated normal and waxy rice starch. *Starch* **51**(7): 249-252.

Malviya R, Srivastava P, Bansal M, Sharma PK. 2010. Mango Peel Pectin as Super disintegrating Agents. *Journal of Scientific and Industrial Research* **69**: 688-690.

Peerzada, N. 1997. Chemical composition of the essential oil of *Hyptis suaveolens. Molecules* **2**: 165-168.

Stevens ES, Willett JL and Shogren RL. 2007. Thermoplastic starch-kraft lignin-glycerol blends. *Journal of Biobased Materials and Bioenergy* **1**: 351-359.

Wurzburz OB. 1964. *Acetylation.* pp.240-241. *In methods of Carbohydrate Cemistry* (Eds. Whistler L, Smith RJ and wolform ML), Academic Press; New York. Vol. IV.

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Water use efficiency and phyto-remediation potential of water hyacinth under elevated CO_2

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ABSTRACT

A pot culture experiment was conducted in Open Top Chambers during 2007-08. The plantlets (ramets) of water hyacinth were grown in pots with four different media (M_1- tap water, M_2- distilled water, M_3- hoagland solution and M_4- hoagland solution with added heavy metals) in three replications and the pots were kept in open top chambers (OTCs), maintained at ambient (360±20ppm) and elevated CO_2 (550±30 ppm), and in open field conditions. Pots in three replications from each media-without plant-were kept under the above three conditions as control to measure the evaporation for WUE estimation. The growth of the plants grown in M_1 and M_2 was severely affected. The plants grown under elevated CO_2 and nutrient rich media (M_3 and M_4) maintained higher green-leaf area over the growth period and recorded higher net assimilation rate (NAR). CO_2 enrichment resulted into reduction of water loss (increased WUE) from plants grown in hoagland (M_3) and heavy metal (M_4) solutions. When the comparison was made in between M_3 and M_4 treatments, there was tremendous increase in WUE (reduced transpirational loss of water per gram of dry matter produced) in plants grown in M_4. the elevated CO_2 enhanced the uptake of heavy metals like Cu, Fe, Mn and Zn in both the media but it was higher in M_4 than in M_3 due to increased availability.

Key words: Water hyacinth, Elevated CO_2, Phytoremediation, Water use Efficiency

At present the need of recycling of waste water is very essential so as to compensate the decrease in water supply. Several methods have been practiced for treatment of waste water. However, there has been an increasing awareness about the potentiality of the vascular hydrophytes for the treatment of waste water and phytoremediation of contaminated soils. Water hyacinth (*Eichhornia crassipes* Mart. Solms) is considered to be one of the most damaging aquatic invasive weed in the world. It made its entry into India at Bengal about 1896 (Biswas and Calder 1954) and now occurs throughout the country in fresh water ponds, pools, tanks, lakes, reservoirs, streams, rivers, irrigation channels and paddy fields. It propagates by vegetative and sexual methods, adapts to changing climate and water quality and can even convert from an aquatic plant to a terrestrial one if its water way dries up. It reduces the volume of available fresh water by increasing the evapo-transpiration. However, the very ecological devastating properties of water hyacinth make it an ideal plant for water treatment and nutrient absorption from waste waters. Its appetite for nutrients and explosive growth rate has been put to use in cleaning up municipal and agricultural waste waters. It has been discovered that water hyacinth's quest for nutrients can be turned in a more useful direction. Its fantastic ability of absorbing nutrients, rapid growth, low economic maintenance and many other profits from the plant raised its value for reducing the pollution. It was recognized to be useful for waste water treatment for removing the heavy metals and other pollutants. The focus on water hyacinth as a key step in waste water recycling is due to the fact that it forms the central unit of recycling engine driven by photosynthesis and therefore the process is sustainable, energy efficient and cost effective under a wide variety of rural and urban conditions.

For many plants, especially those with C_3 photosynthesis, an increase in CO_2 produces an increase in net photosynthetic rate (Morgan *et al.* 2004, Leakey *et al.* 2006). Water hyacinth is most likely a C_3 plant. Unlike submerged macrophytes which are shade plants water hyacinth leaves growing in exposed locations can utilize full sunlight for photosynthesis. Ongoing combustion of fossil fuels leads to an increase in the atmospheric carbon dioxide (CO_2) concentration, which is contributing to global warming substantially (IPCC 2007). It is well known that the elevation of CO_2 in the atmosphere significantly affects global ecosystems (Woodward 2002). General concern about increasing global atmospheric CO_2 levels and given that atmospheric CO_2 levels are doubling in the next

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century it was of interest to determine the response of water hyacinth to elevated CO_2 in terms of water use efficiency and phytoremediation potential.

MATERIALS AND METHODS

The experiment was conducted during 2007-08 in open top chambers (OTCs), maintained at ambient (360±20 ppm) and elevated CO_2 (550±30 ppm), and in open field conditions. Plastic pots (1.5lit capacity) were filled with four different media (Tap water (M_1), Distilled water (M_2), Hoagland solution (M_3) and Hoagland solution with added heavy metals (M_4)) in three replications. Two uniform sized plantlets (ramets) of water hyacinth were placed in each pot and the pots were kept in open top chambers (OTCs), maintained at ambient (360±20 ppm) and elevated CO_2 (550±30 ppm), and in open field conditions. Pots in three replications from each media-without plant-were kept under the above three conditions as control to measure the evaporation for WUE estimation. The experiment was run for 50 days and on every fifth day the loss of water by evapo-transpiration (evaporation in case of control pots) was measured by gravimetric method. The water added (on every 5th day) was summated for the entire experimental period (50 days) to arrive at the cumulative water added (CWA) to pots with plant as well as without plant (control) separately. The cumulative water added to the pots without plants was noted as CWA* and used to correct the evaporation loss. This corrected cumulative water added for each pot (CWA-CWA*) was taken as the cumulative water transpired (CWT) during the experimental period. Water-use efficiency was determined as the ratio of the amount of biomass produced by a plant to the total amount of water transpired. For phyto-remediation studies the media used were Hoagland solution (Taiz and Zeiger 2002) and Hoagland solution with added heavy metals. Heavy metal solution was prepared by doubling the dose of micronutrient solution of Hoagland solution. The water samples were analyzed through Atomic Absorption Spectroscopy (AAS) before the start of the experiment and at the end of the experiment to find out the concentration of heavy metals (Fe, Cu, Mn and Zn).

RESULTS AND DISCUSSION

In water hyacinth leaf petiole and lamina constitute 70-90% of the total plant biomass. So the growth data on leaf and petiole reflect the overall plant growth (Naidu and Paroha 2007). The plant growth was severely affected in the plants grown in tap water and distilled water. This may be due to alkaline pH (8.03) of Tap water and dearth of nutrients in distilled water. The plants grown in M_3 and M_4 produced ten times higher number of leaves than the initial number and the leaf area increase was tremendous. The CO_2 enrichment enhanced the leaf area in both M_3 and M_4 grown plants and the M_4 recorded higher value (Fig. 1). The elevated CO_2 and nutrient rich media (M_3&M_4) maintained the higher green leaf area over the growth period (Fig. 2).

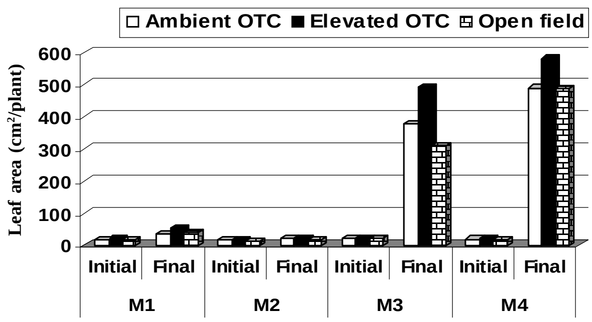

Fig.1. Leaf area in water hyacinth grown in different media under elevated CO_2

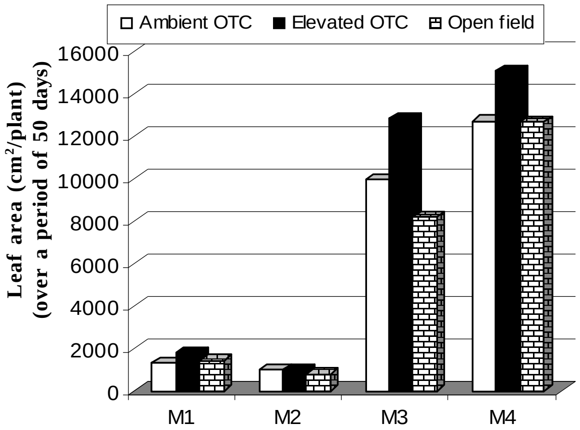

Fig. 2. Leaf Area Duration (LAD) in water hyacinth grown in different media under elevated CO_2

CO_2 enrichment resulted into reduction of water loss (increased WUE) (Naidu and Varshney 2011) from plants grown in Hoagland (M_3) and Heavy metal (M_4) solutions (Fig.3). There was about a 16.7% and 74.5% decrease in water loss under elevated CO_2 than under ambient CO_2 in M_3 and M_4 grown plants respectively. This might be because of enhanced biomass production due to nutrient rich medium and CO_2 enrichment and also because of reduced transpiration due to CO_2 induced stomatal closure (Idso *et al.* 1984). However, when the comparison was made in between M3 and M4 treatments, there was tremendous increase in WUE (reduced transpirational loss of water per gram of dry matter produced) in plants grown in M_4. Here the reason might be production of thick leaves with shiny surface which might have reflected the incident radia-

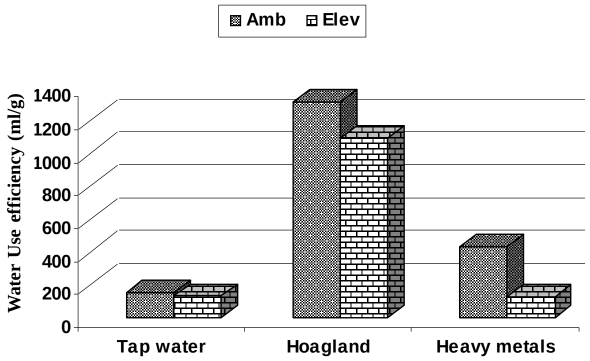

Fig. 3. Water Use efficiency (ml/g) in water hyacinth grown in different media under elevated CO_2

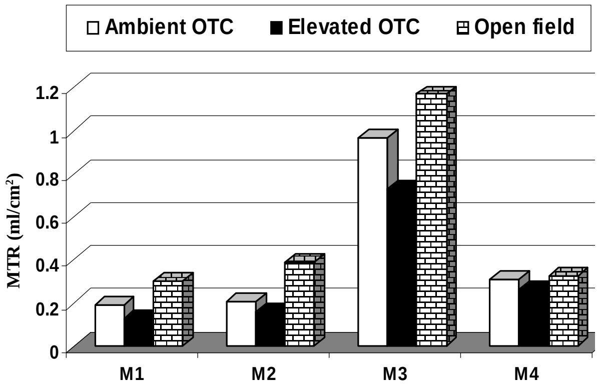

Fig. 4. Mean Transpiration Ratio (MTR) (ml/cm^2) in water hyacinth grown in different media under elevated CO_2

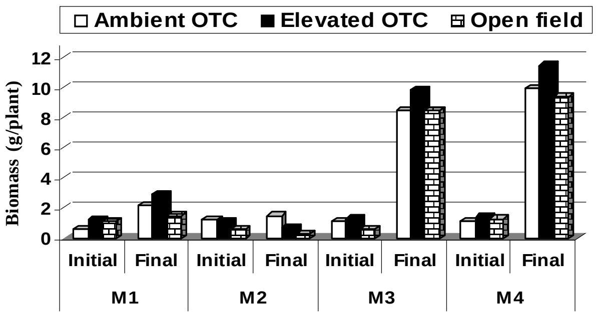

Fig. 5. Plant biomass (g/plant) in water hyacinth grown in different media under elevated CO_2

tion resulting into reduced heat and transpiration. The mean transpiration ratio (MTR), which gives the transpiration per unit leaf area over a period of time, shows (Fig.4) that the elevated CO2 reduced the transpiration and the reduction was high in heavy metal solution. The heavy metal uptake was higher in heavy metal solution than in Hoagland solution (Fig. 6-9). This is due to increased availability of these metals in heavy metal solution. The exposure of the plants to elevated CO_2 resulted into enhanced uptake of these metals in both the media (Fig. 6-9) and this might be due to enhanced growth and associated uptake under high

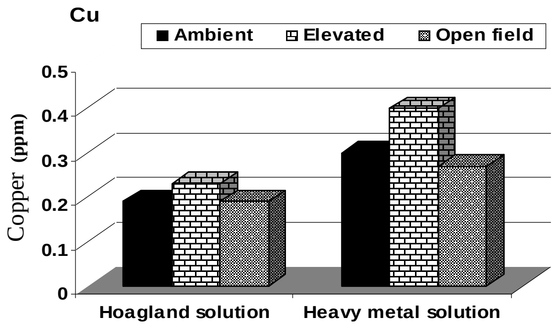

Fig. 6. Copper concentration (ppm) in water hyacinth grown in different media under elevated CO_2

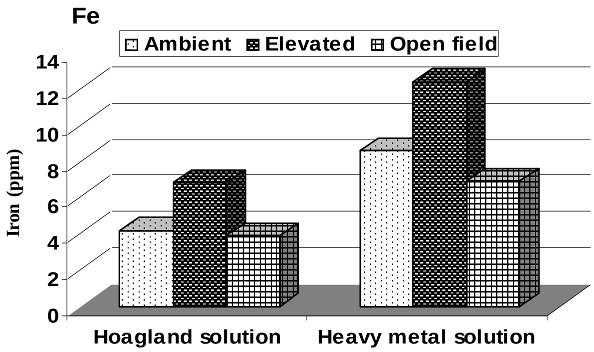

Fig. 7. Iron concentration (ppm) in water hyacinth grown in different media under elevated CO_2

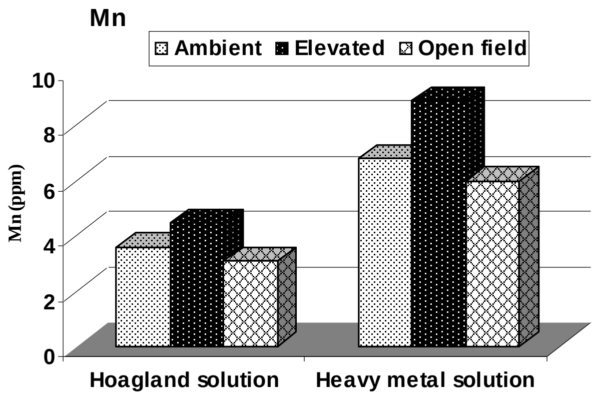

Fig. 8. Manganese concentration (ppm) in water hyacinth grown in different media under elevated CO_2

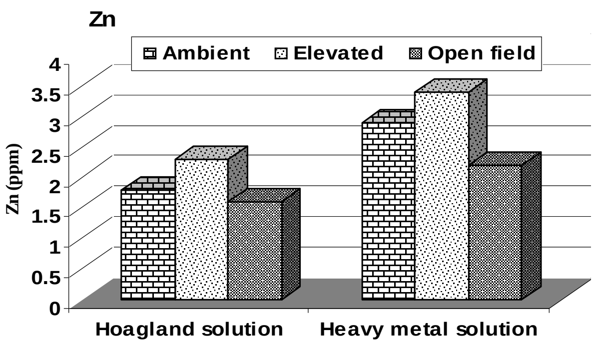

Fig. 9. Zinc concentration (ppm) in water hyacinth grown in different media under elevated CO_2

CO_2 (Idso *et al.* 1985, Zheng *et al.* 2008, Li *et al.* 2012, Song *et al.* 2012). Since the increase of plant biomass resulting from CO2 enhancement (Fig. 5) could suggest that more metal be taken up from the contaminated sites (Tang *et al.* 2003). The results indicate that the ever-increasing atmospheric CO_2 may enhance the phytoremediation efficiency of water hyacinth (Sunghyun Kim and Hojeong Kang 2011). However, this work was limited to a growth chamber, and further investigation is needed in field conditions.

REFERENCES

Biswas K and Calder CC. 1954. *Hand Book of Common Water and Marsh Plants of India and Burma*. 2nd edition, Govt. of India press, Calcutta.177 p.

Idso SB, Kimball BA and Clawson KL. 1984 Quantifying effects of atmospheric CO_2 enrichment on stomatal conductance and evapotranspiration of water hyacinth via infrared thermometry. *Agricultural and Forest Meteorology* **33:** 15-22.

Idso SB, Kimball BA and Anderson MG. 1985. Atmospheric CO_2 enrichment of water hyacinths: Effects on transpiration and water use efficiency. *Water Resources Research* **21**(11): 1787-1790.

IPCC. 200. Climate Change 2007: The physical science basis: Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. *Intergovernmental Panel on Climate Change*. New York, Cambridge University Press.

Leakey ADB, Bernacchi CJ, Ort DR and Long SP. 2006. Long-term growth of soybean at elevated [CO_2] does not cause acclimation of stomatal conductance under fully open air conditions. *Plant Cell and Environment* **29**: 1794-1800.

Li T, Di Z, Han X and Yang X. 2012. Elevated CO_2 improves root growth and cadmium accumulation in the hyper accumulator *Sedum alfredii*. *Plant and Soil* **354**: 325-334.

Morgan JA, Pataki DE and Körner C. 2004. Water relations in grassland and desert ecosystems exposed to elevated atmospheric CO_2. *Oecologia* **140:** 11-25.

Naidu VSGR and Paroha S. 2007. Petiole morphology in water hyacinth (*Eichhornia crassipes* Mart. Solms) is an indication of the nutrient status of the habitat. *Ecology, Environment and Conservation* **13**(2): 221-224.

Naidu VSGR and Varshney Jay G. 2011. Interactive effect of elevated CO2, drought and weed competition on carbon isotope discrimination (A13C) in wheat (*Triticum aestivum*) leaves. *Indian Journal of Agricultural Sciences* **81**(11): 1026-1029.

Song N, Zhang X, Wang F, Zhang C and Tang S. 2012. Elevated CO_2 increases Cs uptake and alters microbial communities and biomass in the rhizosphere of *Phytolacca americana* Linn (pokeweed) and *Amaranthus cruentus* L. (purple amaranth) grown on soils spiked with various levels of Cs. *Journal of Environmental Radioactivity* **112**: 29-37.

Sunghyun Kim and Hojeong Kang. 2011 Effects of elevated CO_2 and Pb on phytoextraction and enzyme activity. *Water Air and Soil Pollution* **219**: 365-375.

Taiz L and Zeiger E. 2002. *Plant Physiology*: 3rd edition, Sinauer Associates, Inc., Publishers, Sunderland, Massachussetts. 764 p.

Tang S, Xi L, Zheng J and Li H. 2003. Response to elevated CO_2 of Indian mustard and sunflower growing on copper contaminated soil. *Bulletin of Environmental Contamination and Toxicology* **71**: 988-997.

Woodward FI. 2002. Potentional impacts of global elevated CO_2 concentrations on plants. *Physiology and Metabolism* **5**: 207-211.

Zheng J, Wang H, Li Z, Tang S and Chen Z. 2008 Using elevated carbon dioxide to enhance copper accumulation in *Pteridium revolutum*, a copper-tolerant plant, under experimental conditions. *International Journal of Phytoremediation*, **10**(2): 159-170.

Short communication

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Residual effect of cluster bean herbicides on succeeding wheat crop

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Cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.), popularly known as 'Guar', is grown during rainy season in semi-arid and arid regions of India. Cluster bean is grown for different purposes from very ancient time. A seed of cluster bean contains 28-33% gum which is used in almost all types of industries, *viz.* textiles, paper, petroleum, pharmaceuticals, food processing, cosmetics, mining explosives, oil drilling *etc*. Cluster bean adds to the fertility of soil by fixing considerable amount of atmospheric nitrogen (Naagar and Meena 2004). As per past 10 years average, guar is being cultivated in India on about 3 million ha with a production of about 1.2 million tons with year to year variation especially in the years of drought as well as on high market demand. Rajasthan contributes 83% to the area and 65% to the production. In 2012, world-wide, about 0.45 million tons of guar products were traded with export value of US$ 4,623 million out of which share of Indian export was 80.8% (0.37 million tonnes) worth US$ 3,916 million. Among all the agricultural export commodities, cluster bean has become the highest foreign exchange earner of `.212.87 billions followed by Basmati rice in the recent year of 2012-13 (NRAA 2014).

As guar is a rainy season crop and due to frequent rains, weed population increase tremendously and compete for nutrients, moisture and space with crop causing considerable yield reduction. Besides, this period coincides with the season of peak labour activity leading to scarcity of labour for weeding. All this add to high cost of production too. Proper weed control method is the prime need and it is very much essential to give the herbicide usage its due share to obtain maximum productivity. Imazethapyr is imidazolinone herbicide and may be applied pre plant incorporated, pre-emergence, ground cracking, or post-emergence for effective weed control (Wilcut *et al.* 1995). Imazethapyr applied as pre-plant incorporated or as pre-emergence controls many troublesome weeds such as coffee senna (*Cassia occidentalis* L.), common lambsquarter (*Chenopodium album* L.), morning-glory species (*Ipomoea* spp.), pigweed species (*Amaranthus* spp.) including Palmer amaranth (*Amaranthus palmeri*), prickly sida (*Sida spinosa* L.), purple and yellow nutsedge (*Cyperus rotundus* L. and C. *esculentus* L.), spurred anoda (*Anoda cristata* L.), and wild poinsettia (*Euphorbia heterophylla* L.). Imazethapyr applied as post-emergence provides broad spectrum and most consistent control when applied within 10 days of weed emergence. Imazethapyr is the only post-emergence herbicides for effective control of both yellow and purple nutsedges (Richburg *et al.* 1993). Control is most effective when imazethapyr is applied to the soil or to yellow nutsedge that is no more than 13 cm tall (Richburg *et al.* 1993). Therefore keeping these points in view, present study was carried out to find out suitable herbicide and their dose for controlling weeds in guar crop**.**

A field experiment was carried out at Bathinda during *Kharif* 2012. The soil of experimental site was sandy loam, medium in available N (275 kg/ha), P (16 kg/ha), K (221 kg/ha), medium in organic carbon content (0.67%) and slightly alkaline in reaction with pH 8.2. The experiment comprised 12 treatment combinations, *viz.* imazethapyr 40 g/ha, imazethapyr +imazamox 40 g/ha, quizalofop-ethyl 37.5 g/ha, fenoxaprop-p-ethyl 50 g/ha, pendimethalin + imazethapyr 750 + 40 g/ha, pendimethalin + (imazethapyr + imazamox 750+40 g/ha, pendimethalin + quizalofop-ethyl 750+37.5 g/ha, pendimethalin + quizalofop-ethyl 750 + 37.5 g/ha, pendimethalin + fenoxaprop-p-ethyl 750+50 g/ha, pendimethalin 750 g/ha, weeding at 3-4 weed leaf stage, weed free and weedy check. These treatments were evaluated in randomized block design with three replications. Cluster bean variety '*AG-112*' was sown 11 July 2012 at 45 x 10 cm row and plant to plant spacing with a seed rate of 20 kg/ha. Crop growth parameters, *viz.* plant height was recorded at 60 DAS. Number of pods per plant,

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hundred seed weight and seed yield were observed at harvest. Weed intensity and dry weight were recorded at 60 DAS stage of crop growth. Weed control efficiency (WCE) was computed on the basis of total dry matter of weeds at 60 DAS stage of crop growth. Phytotoxicity of different treatments on crop in terms of chlorosis, malformed plants, epinasty, hyponasty, necrosis, vein clearing and wilting, *etc*. was visually observed in each plot. The nutrient uptake by crop and weeds (kg/ha) was computed by using the following formula:

Weed intensity: All the weed control treatments resulted significantly less grassy, broad leaf weeds, sedges and total weed intensity as compared to weedy check at 60 DAS (Table 1). Pendimethalin 750 g/ha followed by imazethapyr 40 g/ha resulted significantly less grassy, broad-leaf weeds, and total weed intensity and pendimethalin 750 g/ha followed by imazethapyr + imazamox (Odyssey) 40 g/ha recorded less sedges as compared to other treatments while both these treatments were at par to each at 60 DAS. Imazethapyr 40 g/ha alone resulted in significantly less population of broad-leaf weeds, sedges and total weeds as compared to quizalofop-ethyl 37.5 g/ha, fenoxaprop-p-ethyl 50 g/ha, pendimethalin 750 g/ha, pendimethalin 750 g/ha followed by quizalofop-ethyl 37.5 g/ha and pendimethalin 750 g/ha followed fenoxaprop-p-ethyl 50 g/ha while at par to imazethapyr + imazamox (Odyssey) 40 g/ha and weeding at 3-4 weed leaf stage at 60 DAS. Imazethapyr + imazamox (Odyssey) 40 g/ha recorded less grassy weeds which was at par to imazethapyr 40 g/ha, pendimethalin 750 g/ha followed by quizalofop-ethyl 37.5 g/ha, pendimethalin 750 g/ha followed by fenoxaprop-p-ethyl 50 g/ha and weeding at 3-4 weed leaf stage while significantly higher than quizalofop-ethyl 37.5 g/ha, fenoxaprop-p-ethyl 50 g/ha, pendimethalin 750 g/ha at 60 DAS stage of crop growth.

Weed dry weight: All the weed control treatments significantly reduced dry matter accumulation of grassy, broad-leaf weeds, sedges and total weed dry matter accumulation as compared to weedy check at 60 DAS stage of crop growth (Table 1). Minimum dry matter accumulation of grassy, broad-leaf weeds, sedges and total weed dry weight were recorded with pendimethalin 750 g/ha followed by imazethapyr 40 g/ha and pendimethalin 750 g/ha followed by imazethapyr + imazamox (Odyssey) 40 g/ha which

Table 1. Effect of treatments on weed intensity and dry matter accumulation at 60 DAS

Treatment	Dose g/ha	Weed intensity (no./m^2)				Weed dry matter accumulation (g/m^2)				Weed control efficiency (%)
		Grassy	Broad-leaved	Sedges	Total	Grassy	Broad-leaved	Sedges	Total	
Imazethapyr	40	4.9 (23.5)	3.8 (14.2)	2.5 (5.5)	6.3 (43.2)	6.4 (39.7)	5.2 (28.0)	3.9 (15.7)	8.9 (83.5)	78.6
Imazethapyr +imazamox	40	4.9 (23.7)	4.8 (22.5)	2.8 (7.5)	7.3 (53.7)	6.9 (47.5)	6.1 (40.0)	4.3 (18.0)	10.2 (105)	72.0
Quizalofop-ethyl	37.5	5.8 (33.5)	8.0 (63.5)	2.9 (8.2)	10.3 (106.5)	8.4 (70.7)	11.2 (126)	4.7 (21.5)	14.7 (218)	41.5
Fenoxaprop-p-ethyl	50	7.1 (51.0)	7.9 (62.5)	2.9 (8.0)	11.1 (121.5)	8.3 (68.2)	11.4 (130)	3.8 (15.2)	14.6 (213)	43.0
Pendimethalin + imazethapyr	750+ 40	2.6 (6.5)	2.8 (7.2)	3.3 (10.0)	4.9 (23.7)	4.3 (18.0)	4.0 (15.2)	3.5 (12.2)	6.8 (45.5)	88.0
Pendimethalin + imazethapyr + imazamox	750+ 40	3.2 (10.0)	3.0 (8.2)	3.1 (8.5)	5.1 (26.7)	5.1 (25.0)	3.3 (10.2)	3.9 (14.7)	7.1 (50.0)	86.6
Pendimethalin + quizalofop-ethyl	750+ 37.5	4.2 (17.5)	6.7 (45.2)	3.4 (11.2)	8.6 (74)	6.3 (40.0)	8.8 (78.5)	4.8 (23.0)	11.8 (141)	62.6
Pendimethalin + fenoxaprop-p-ethyl	750+ 50	3.5 (12.0)	6.1 (37.5)	2.8 (7.7)	7.6 (57.2)	5.7 (33.7)	8.3 (69.0)	4.7 (22.0)	11.2 (124)	66.9
Pendimethalin	750	7.2 (52.0)	6.4 (41.2)	3.3 (10.5)	10.2 (103)	9.8 (95.7)	8.3 (70.0)	3.9 (15.0)	13.5 (180)	52.0
Weeding at 3-4 weed leaf stage	-	5.2 (27.2)	3.8 (14.2)	2.7 (7.2)	6.9 (48.7)	7.6 (57.5)	6.7 (45.0)	3.6 (12.7)	10.7 (115)	69.9
Weed free	-	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	100
Weedy	-	11.5 (132)	8.2 (67.5)	4.3 (17.7)	14.7 (218)	14.4 (14.4)	12.1 (12.1)	5.6 (32.2)	19.5 (384)	0.0
LSD (P=0.05)	-	0.75	0.69	0.67	1.25	0.97	1.15	0.78	1.31	4.77

Original values are in parentheses

were at par to each other and significantly superior to other treatments at 60 DAS stage of crop growth. An alone application of imazethapyr 40 g/ha and imazethapyr + imazamox (Odyssey) 40 g/ha resulted significantly less dry matter accumulation of grassy, broad-leaf weeds, sedges and total weed dry weight as compared to quizalofop-ethyl 37.5 g/ha, fenoxaprop-p-ethyl 50 g/ha, pendimethalin 750 g/ha, pendimethalin 750 g/ha followed by quizalofop-ethyl 37.5 g/ha, pendimethalin 750 g/ha followed by fenoxaprop-p-ethyl 50 g/ha and weeding at 3-4 weed leaf stage while at par to each other at 60 DAS stage of crop growth. Results so obtained were in close conformity with the findings of Yadav *et al.* (2011).

Weed control efficiency (WCE): The highest weed control efficiency was recorded under weed free treatment (Table 1). Among other weed control treatments, weed control efficiency was highest under pendimethalin 750 g/ha followed by imazethapyr 40 g/ha which was at par to pendimethalin 750 g/ha followed by imazethapyr +imazamox (Odyssey) 40 g/ha and significantly higher than other treatments of weed control at 60 DAS stage. An alone application of imazethapyr 40 g/ha resulted significantly higher weed control efficiency as compared to quizalofop-ethyl 37.5 g/ha, fenoxaprop-p-ethyl 50 g/ha, pendimethalin 750 g/ha, pendimethalin 750 g/ha followed by quizalofop-ethyl 37.5 g/ha, pendimethalin 750 g/ha followed by fenoxaprop-p-ethyl 50 g/ha and weeding at 3-4 weed leaf stage. Weed control efficiency increased with the application of imazethapyr was also reported by Yadav *et al.* (2011).

Nutrient uptake by weeds: All weed control treatments significantly reduced N, P and K uptake by weeds as compared to weedy check (Table 2). The minimum uptake of N, P and K was observed with pendimethalin 750 g/ha followed by imazethapyr 40 g/ha being at par with pendimethalin 750 g/ha followed by imazethapyr + imazamox 40 g/ha and significantly less than other treatments at harvest stage. Reduced nutrient uptake by weeds under the influence of different weed control measures have also been reported by Chhokar *et al.* (1997) and Yadav *et al.* (2011).

Growth parameters: Imazethapyr, imazethapyr + imazamox, quizalofop-ethyl, fenoxaprop-p-ethyl and pendimethalin at all doses and all combinations did not significantly affected plant height (data not given). At 60 DAS, minimum plant height were observed with imazethapyr 40 g/ha, imazethapyr + imazamox 40 g/ha, pendimethalin 750 g/ha followed by imazethapyr 40 g/ha, pendimethalin 750 g/ha *fb* imazethapyr + imazamox 40 g/ha and pendimethalin 750 g/ha *fb* quizalofop-ethyl 37.5 g/ha although the difference were non- significant to each other and other treatments of weed control.

Yield and yield attributing characters: All weed control treatments significantly increased the yield attributing characters and seed yield of cluster bean over weedy control (Table 2). Maximum numbers of pods per plant were observed with pendimethalin 750 g/ha followed by imazethapyr 40 g/ha and pend-imethalin 750 g/ha followed by imazethapyr + imaz-amox 40 g/ha which were at par with imazethapyr 40 g/ha, imazethapyr 40 g/ha, imazethapyr + imaza- mox 40 g/ha, weeding at 3-4 weed leaf stage and weed free and significantly higher than other treatments of weed control. 100-seed weight was significantly affected by different weed control treatments and highest was observed with pendimethalin 750 g/ha followed by imazethapyr 40 g/ha and pendimethalin 750 g/ha followed by imazethapyr + imazamox 40 g/ha which was at par with imazethapyr 40 g/ha, imazethapyr + imazamox 40 g/ha and significantly higher than quizalofop-ethyl 37.5 g/ha, fenoxaprop-p-ethyl 50 g/ha, pendimethalin 750 g/ha, pendimethalin 750 g/ha followed by quizalofop-ethyl 37.5 g/ha, pendimethalin 750 g/ha followed by fenoxaprop-p-ethyl 50 g/ha, weeding at 3-4 weed leaf stage and weed free. The maximum seed yield was observed with weed free check which was at par with pendimethalin 750 g/ha followed by imazethapyr 40 g/ha and significantly higher than rest of treatments. The increased seed yield with application of imazethapyr in clusterbean by Yadav *et al* (2011).

Phytotoxicity symptoms and crop safety: The application of imazethapyr, imazethapyr + imazamox (Odyssey), quizalofop-ethyl, fenoxaprop-p-ethyl and pendimethalin at all doses and combinations resulted no phytotoxicity symptoms on cluster bean crop at all the stages of crop growth (Table 3). No phytotoxicity symptoms of imazethapyr, quizalofop-ethyl, and pendimethalin did not result any phytotoxicity on guar crop was also reported by Yadav *et al.* (2011).

Economics: The maximum cost of cultivation was observed with weed free treatment (` 24100/ha) (Table 2). The maximum gross return (` 50,401/ha) was observed with weed free which was at par with pendimethalin 750 g/ha followed by imazethapyr 40 g/ha ('49,150/ha) and significantly higher than other treatment of weed control. The application pendimethalin 750 g/ha followed by imazethapyr 40 g/ha result maximum net return (` 33,118/ha) and B:C ratio (2.07) which was almost significantly higher than other treatments of weed control. Imazethapyr at lower rate 100 g/ha with chlorimuron 24 g/ha also found more remunerative in groundnut as it fetched the maxi-

Table 2. Effect of different weed control treatments on yield and economics of guar and nutrients uptake by weeds and crop at harvest

Treatment	Dose g/ha	Pods/ plants (no.)	100-seed weight (g)	Seed yield (kg/ha)	Gross return ($x10^3$ `/ha)	Net returns ($x10^3$ `/ha)	B:C Ratio	Nutrients uptake by weeds (kg/ha)			Nutrients uptake by crop (kg/ha)		
								N	P	K	N	P	K
Imazethapyr	40	71.0	3.1	432.3	43.23	28.47	1.93	4.4 (18.4)	1.8 (2.5)	4.5 (19.6)	99.2	30.0	135.0
Imazethapyr +imazamox	40	71.6	3.1	424.8	42.47	27.42	1.82	4.5 (19.4)	2.1 (3.2)	4.6 (20.9)	98.0	29.1	131.8
Quizalofop-ethyl	37.5	48.0	2.9	339.2	33.92	18.70	1.23	4.8 (22.9)	2.2 (3.7)	4.9 (23.6)	85.3	22.0	122.0
Fenoxaprop-p-ethyl	50	46.5	3.0	306.9	30.70	15.89	1.07	5.1 (25.5)	2.2 (4.0)	5.2 (26.5)	82.4	22.6	119.4
Pendimethalin + imazethapyr	750+ 40	75.5	3.1	491.5	49.15	33.12	2.07	3.7 (13.4)	1.7 (2.1)	3.8 (14.0)	109.5	30.6	141.1
Pendimethalin +(imazethapyr + imazamox)	750+ 40	75.5	3.1	428.7	42.87	26.54	1.62	4.1 (16.1)	1.8 (2.4)	4.2 (16.7)	101.1	28.4	136.5
Pendimethalin + quizalofop-ethyl	750+ 37.5	54.4	2.9	359.5	35.95	19.46	1.18	4.3 (18.0)	2.1 (3.5)	4.4 (18.9)	80.7	19.8	134.9
Pendimethalin + fenoxaprop-p-ethyl	750+ 50	66.2	2.9	335.8	33.58	17.49	1.09	4.7 (21.8)	2.2 (3.7)	4.8 (22.4)	78.6	20.5	133.9
Pendimethalin	750	50.5	2.9	348.5	34.85	19.50	1.27	4.6 (21.0)	2.2 (3.9)	4.7 (21.4)	81.4	15.8	120.7
Weeding at 3-4 weed leaf stage	-	65.1	3.0	357.4	35.74	17.08	0.91	4.4 (18.8)	2.1 (3.3)	4.5 (19.3)	78.8	23.2	122.0
Weed free	-	68.3	2.9	504.0	50.40	26.30	1.09	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	117.5	32.8	142.6
Weedy	-	38.4	2.4	246.2	24.62	10.55	0.75	10.5 (110)	4.1 (15.8)	12.2 (149)	38.8	9.4	42.8
LSD (P=0.05)	-	13.37	0.21	69.92	6.99	3.79	0.24	0.22	0.16	0.26	7.02	3.21	4.04

Original values are in parentheses

Table 3. Residual effect of different weed control treatments on growth parameter, yields attributes and yields of succeeding wheat crop

Treatment	Dose g/ha	Germination (%)	Plant height (cm)	Number of tillers/m^2	Number of spike/m^2	Number of grains/ spike	1000-grain weight (g)	Grain yield (t/ha)
Imazethapyr	40	53.1(63.8)	75	305	298	46	37	5.84
Imazethapyr + imazamox	40	53.8 (65.2)	68	309	278	49	36	5.91
Quizalofop-ethyl	37.5	56.4 (69.4)	73	311	298	45	38	5.78
Fenoxaprop-p-ethyl	50	56.1(68.7)	69	302	300	43	37	5.86
Pendimethalin + imazethapyr	750+40	56.0 (68.7)	76	301	281	46	38	5.71
Pendimethalin + imazethapyr + imazamox	750+40	54.7 (66.6)	73	302	291	48	36	5.90
Pendimethalin + quizalofop-ethyl	750+37.5	55.6 (68.0)	68	320	298	45	38	5.70
Pendimethalin + fenoxaprop-p-ethyl	750+50	52.6 (63.1)	69	310	291	46	39	5.84
Pendimethalin	750	54.3 (65.9)	71	299	290	43	38	5.87
Weeding at 3-4 weed leaf stage	-	55.5 (68.0)	72	306	291	44	37	5.88
Weed free	-	53.8 (65.2)	73	310	281	45	38	5.70
Weedy	-	56.4 (69.4)	70	318	292	48	37	5.79
LSD (P=0.05)	-	NS	NS	NS	NS	NS	NS	NS

Original values are in parentheses

mum values of net monetary returns (`14,096/ha) and benefit: cost ratio (1.8) and surpassed recommended practice of weed control, *viz.* hand weeding twice which recorded the inferior values of net monetary returns (` 10,194/ha) and B: C ratio (1.4) due to more cost of labour.

Nutrient uptake by crop: All the weed control treatments recorded significant increase in N, P and K uptake by the crop compared to weedy check (Table 2). The maximum uptake of N, P and K was observed with weed free treatment at harvest stage. The application of pendimethalin 750 g/ha followed by imazethapyr 40 g/ha result significantly higher uptake of N, P and K which was at par to pendimethalin 750 g/ha followed by imazethapyr + imazamox40 g/ha and almost significantly higher than other treatments of weed control at harvest stage. Similar findings that application of imazethapyr increased uptake of nutrients in guar crop was reported by Yadav *et al.* 2011.

Residual effect on succeeding wheat crop

The application of imazethapyr, imazethapyr + imazamox (Odyssey), quizalofop-ethyl, fenoxaprop-p-ethyl and pendimethalin at all doses and combinations resulted no residual effect on growth, development and yield of succeeding wheat crop (Table 3).

SUMMARY

A field experiment was carried out at Punjab Agricultural University, Regional Research Station, Bathinda during *Kharif* 2012. Pendimethalin 750 g/ha followed by imazethapyr 40 g/ha results minimum weed intensity and weed dry matter accumulation and maximum yield attributes and yield except weed free. The application of pendimethalin 750 g/ha followed by imazethapyr 40 g/ha resulted maximum net return (` 33,118/ha) and b:c ratio (2.07) which was more than other treatments of weed control. Imazethapyr, imazethapyr + imazamox, quizalofop-ethyl, fenoxaprop-p-ethyl and pendimethalin at all doses and combinations resulted no phytotoxicity symptoms on guar crop and no residual effect on succeeding wheat crop.

REFERENCES

Chhokar RS, Balyan RS and Pahuja SS. 1997. Nutrient removal of weeds on soybean under integrated weed management. *Indian Journal of Agronomy* **42**: 138-141.

Dhaker H, Mundra SL and Jain NK. 2009. Weed management in cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]. *Indian Journal of Weed Science* **41**: 224-227.

Naagar K and Meena NC. 2004. Effect of phosphorus, sulphur and phosphate solubilizing bacteria on yield component, yield and quality of clusterbean *Cyamopsis tetragonoloba* (L.). *Legume Research* **27**(1): 27-31.

Nelson KA, Renner KA and Penner D. 1998. Weed control in soybean (*Glycine max*) with imazamox (Odyssey) and imazethapyr. *Weed Science* **46**(5): 587-594.

NRAA. 2014. *Potential of rainfed guar (Cluster beans) Cultivation, Processing and Export in India.* Policy paper No.3. National Rainfed Area Authority, NASC Complex.D PS Marg, New Delhi-110012, India: 109 p.

Richburg JS, Wilcut JW and Wehtje GR. 1993. Toxicity of foliar and/or soil applied AC 263,222 to purple (*Cyperus rotundus*) and yellow nutsedge (C. *esculentus*). *Weed Science* **42**: 398-402.

Shete BT, Patil HM and Ilhe SS. 2008. Effect of cultural practices and post-emergence herbicides against weed control in soybean. *Journal of Maharashtra Agriculture University* **33**: 118-119.

Singh Smita, Kewat ML, Dubey Megha, Shukla UN and Sharma JK. 2014. Efficacy of imazethapyr on weed dynamics, yield potential and economics of groundnut (*Arachis hypogaea* L.) *Legume Research* **37**(1): 87-92.

Vyas MD and Kushwah SS. 2008. Effect of cultural and chemical methods on growth and yield of soybean in Vindhynagar plateau of Madhya Pradesh. *Indian Journal of Weed Science* **40**: 92-94.

Wilcut JW, York AC, Grichar WJ and Wehtje GR. 1995. The biology and management of weeds in peanut (*Arachis hypogaea*), pp. 207-244. In: *Advances in Peanut Science*, (Eds. Pattee HE and Stalker HL), American Peanut Research Education Society, Stillwater, OK, USA.

Yadav SL, Kaushik MK and Mundra SL. 2011. Effect of weed control practices on weed dry weight, nutrient uptake and yield of cluster bean under rainfed condition. *Indian Journal of Weed Science* **43** (1&2): 81-84.

Short communication

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Carfentrazone and pinoxaden with and without surfactant against grasses and broad-leaf weeds in wheat

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Wheat crop is infested with both grassy and broad-leaf weeds. Competition from weeds throughout the crop season culminates yield losses ranging from 10 to 70% depending upon time and intensity of weed flora. In South-Western Haryana, infestation of *Avena ludoviciana* is increasing at an alarming rate in wheat due to use of high inputs like fertilizers and irrigations. In North-Eastern Haryana, wheat crop grown mainly after rice is infested with *Phalaris minor* along with broad-leaf weeds such as *Rumex dentatus, Anagallis arvensis, Chenopodium album, Convolvulus arvensis* and *Malva parviflora.* So there was urgent need for broad spectrum herbicides which can provide effective control of both grassy as well as broad-leaf weeds in wheat crop.

A post-emergence herbicide pinoxaden at 40-60 g/ha was recored very effective against *Avena ludoviciana* and resistant population of *P. minor* without any phytotoxicity to wheat crop (Yadav *et al*. 2009). For control of broad-leaf weeds, metsulfuron and 2,4-D are being widely used, but these herbicides do not provide any control of *C. arvensis, Solanum nigrum* and *Malva parviflora* for which carfentrazone is very effective (Punia *et al*. 2006, Walia and Singh 2006). Therefore to find out effective herbicide combination for complex weed flora, the present investigation was planned with the objectives to evaluate the efficacy of carfentrazone and pinoxaden with and without surfactant against grasses and broad-leaf weeds in wheat crop.

Experiment was conducted during *Rabi* seasons of 2008-09 and 2009-10, at Agronomy Research Area of CCS Haryana Agricultural University, Hisar. The experimental soil was sandy loam (Typic Ustochrepts) with 61% sand, 22.1% silt and 19.1% clay, with 0.29% organic carbon and pH of 8.2. Wheat variety *'PBW 343'* was drilled on November 18, 2008 and December 10, 2009 in a plot size of 7.0 x 4.2 m^2, by using seed rate of 100 kg/ha. The study was arranged in randomized block design and replicated thrice. Recommended dose of fertilizers and irrigations were applied uniformly in all plots. The treatments comprising of pinoxaden (5 EC) at 30, 35 and 40 g/ha and carfentrazone along with 1% ammonium sulphate applied at 15, 20 and 25 g/ha as sequential application 7 days before or after pinoxaden use were applied at 35 and 42 DAS by flat fan nozzle at a volume of 375 L/ha of water (Table 1). Additional treatments of carfentrazone 25 g *fb* pinoxaden 50 g/ha and pinoxaden 50 g/ha *fb* carfentrazone 25g along with 1% ammonium sulphate were also included during second year.

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Observations for weed population and their dry matter accumulation were recorded at 60 DAT with the help of random quadrate (0.5 x 0.5 m) at four places in each plot and then converted into per m^2. Data was subjected to square root ($\sqrt{x+1}$) transformation to normalize their distribution before analysis. Data on per cent visual control by herbicides recorded on 0-100 scale was transformed by using arcsin transformation method and data on yield attributes and grain yield of wheat was also recorded at harvest which was statistically analyzed using analysis of variance.

The experimental field was infested with natural population of grassy (84% and 87%) and broad-leaf weeds (16% & 13%), respectively during both the 2008-09 and 2009-10, respectively. The dominant weeds were little seed canary grass (*Phalaris minor* Retz.) among grassy weeds and *Chenopodium album* L., *Convolvulus arvensis* and *Melilotus indica* among broad-leaf weeds. Density and dry weight of different grassy and broad-leaf weeds were significantly affected by herbicides treatments as compared to untreated check at 30 days after application (Table 1). Although, pinoxaden at the all doses provided excellent control of grassy weeds but did not show any efficacy against broad-leaf weeds (Table 1). Efficacy of herbicide on grassy and broad-leaf weeds increased significantly with increasing the dose of pinoxaden and

Table 1. Effect of different herbicide doses on density and dry weight of weeds, and grain yield of wheat (2008-09 and 2009-10)

Treatment	Weed density (no./m^2) at 60 DAT					Weed dry weight (g/m^2) at 60 DAT	
	2008-09		2009-10				
	P. minor	*C. album*	*P. minor*	*C. album*	*Convolvulus arvensis*	2008-09	2009-10
Carfentrazone 15 g *fb* pinoxaden 30 g/ha	1.3(0.7)	1.5(1.3)	3.0 (8.2)	1.8 (2.3)	1.9 (2.7)	137.3	120.7
Carfentrazone 20 g *fb* pinoxaden 35 g/ha	1.4(1.0)	1.3(0.7)	2.7 (6.3)	1.3 (0.7)	1(0)	133	88.7
Carfentrazone 25 g *fb* pinoxaden 40 g/ha	1.3(0.7)	1(0)	1.5(1.3)	1.3(0.7)	1(0)	62.7	56.3
Carfentrazone 25 g *fb* pinoxaden 50 g/ha	-	-	1(0)	1(0)	1(0)	-	44.0
Pinoxaden 30 g/ha *fb* Carfentrazone 15 g (ammonium sulphate 1%)	1.1(0.3)	1.1(0.3)	3.2(9.4)	1.6(1.7)	1.8(2.3)	232	99.3
Pinoxaden 35 g/ha *fb* Carfentrazone 20 g (ammonium sulphate 1%)	1.3(0.7)	1.1(0.3)	2.6(5.6)	1.3(0.6)	1(0)	128	68.0
Pinoxaden 40 g/ha *fb* Carfentrazone 25 g (ammonium sulphate 1%)	1(0)	1(0)	1.5(1.3)	1(0)	1(0)	0	38.0
Pinoxaden 50 g/ha *fb* carfentrazone 25 g (ammonium sulphate 1%)	-	-	1(0)	1(0)	1(0)	-	35.3
Carfentrazone 25 g/ha	2.6(5.6)	1(0)	7.0(48.2)	1(0)	1(0)	592.6	323.3
Pinoxaden 40 g/ha	1.1(0.3)	2.9(4)	1.5(1.3)	2.7(6.3)	2.3(4.3)	177.3	94.3
Weed free	1.0(0)	1(0)	1(0)	1(0)	1(0)	0	0.0
Weedy check	6.5(42)	2.3(4.3)	7.3(52)	2.7(6.3)	2.4(5.0)	602.6	400.3
LSD (P=0.05)	0.91	0.32	1.2	0.37	0.42	9.3	16.5

Original values are in parentheses

Table 2. Effect of different herbicide combinations on weed control efficiency and grain yield of wheat (2008-09 and 2009-10)

Treatment	Weed control efficiency (%)		Grain yield (t/ha)	
	2008-09	2009-10	2008-09	2009-10
Carfentrazone 15 g *fb* pinoxaden 30 g/ha	77.2	69.8	4.29	3.61
Carfentrazone 20 g *fb* pinoxaden 35 g/ha	77.9	77.8	4.50	3.79
Carfentrazone 25 g *fb* pinoxaden 40 g/ha	89.5	85.9	4.60	3.78
Carfentrazone 25 g *fb* pinoxaden 50 g/ha	89	89	4.06	4.06
Pinoxaden 30 g/ha *fb* carfentrazone 15 g (Ammonium sulphate 1%)	78.1	75.1	4.36	3.87
Pinoxaden 35 g/ha *fb* carfentrazone 20 g (Ammonium sulphate 1%)	78.7	83.0	4.42	3.84
Pinoxaden 40 g/ha *fb* carfentrazone 25 g (Ammonium sulphate 1%)	100	90.5	4.85	3.91
Pinoxaden 50 g/ha *fb* carfentrazone 25 g (Ammonium sulphate 1%)	75.1	91.1	3.87	4.18
Carfentrazone 25 g/ha	1.2	19.2	4.13	3.67
Pinoxaden 40 g/ha	70.5	76.4	4.55	3.85
Weed free	100	100	4.83	4.00
Weedy check	0.0	0.0	3.83	3.41
LSD (P=0.05)	2.6	2.6	0.14	0.29

carfentrazone during both the years of investigation. Application of carfentrazone at 25 g/ha provided complete control of broad-leaf weeds. As shown by WCE (%), sequential application of pinoxaden at 40 g/ha *fb* carfentrazone 25 g/ha and adding ammonium sulphate proved significantly effective in reducing density and biomass of weeds and gave 100% control of grassy and broad-leaf weeds without any phytotoxic effect on crop during 2008-09 while during 2009-10, sequential application of pinoxaden at 50 g/ha with carfentrazone 25 g/ha along with 1% of ammonium sulphate gave complete control of grassy and broad-leaf weeds without any phytotoxic effect on wheat crop (data not given). This is in conformity with earlier findings of Katara *et al.* (2013) and Shoeran *et al.* (2013). During first year, use of carfentrazone 25 g/ha at 35 DAS and pinoxaden 40 g/ha at 7 days after carfentrazone use was not as effective against the *P. minor* as pinoxaden use at 35 days after sowing but application of carfentrazone 25 g/ha at 35 DAS and sequential application of pinoxaden 40 and 50 g/ha at 7 days after carfentrazone use was equally effective against *P. minor* as pinoxaden used at 35 days after sowing.

All the herbicide treatments registered significantly higher crop yield over weedy check during both the years of experimentation (Table 1 and 2). Presence of weeds throughout crop season reduced wheat yield by 20.6 and 14.8% as compared to weed free situations in 2008-09 and 2009-10, respectively. During 2008-09, maximum grain yield (4.85 t/ha) was recorded with the application of pinoxaden at 40 g/ha (35 DAS) *fb* sequential application of carfentrazone 20 g/ha (42 DAS) with 1% solution of ammonium sulphate which was at par with weed free check and significantly superior to all other herbicide treatments while during 2009-10, maximum grain yield (4.18 t/ha) was recorded with the application of pinoxaden at 50 g/ha (35 DAS) with sequential use of carfentrazone 25 g/ha (42 DAS) along with 1% solution of ammonium sulphate which was at par with combination of pinoxaden 40 g/ha *fb* carfentrazone 25 g (ammonium sulphate 1%), carfentrazone 25 g *fb* pinoxaden 50 g/ha which was even 4.5% higher than weed free check.

The present investigation conclusively inferred that post-emergence application of pinoxaden 40 g/ha at 35 DAS and carfentrazone 25g/ha at 42 DAS is very effective to control grassy as well as broadleaf weeds without any injury to wheat crop.

SUMMARY

Experiment to evaluate the bioefficacy of pinoxaden 5 EC in combination with carfentrazone in wheat was conducted in sandy loam soil at CCS HAU Hisar during *Rabi* seasons of 2008-09 and 2009-10, at Agronomy Research Area of CCS Haryana Agricultural University, Hisar. The dominant weeds present in experimental field were little seed canary grass (*Phalaris minor* Retz.) among grassy weeds and *Chenopodium album*, *Convolvulus arvensis* and *Melilotus indica* among broadleaf weeds. Use of carfentrazone 25 g/ha at 35 DAS and pinoxaden 40 g/ha 7 days after carfentrazone use was not as effective against *P.minor* as pinoxaden use at 35 days after sowing. Post-emergence use of pinoxaden at 50 g/ha (35 DAS) with sequential use carfentrazone at 25 g/ha (42 DAS) with 1% ammonium sulphate provided complete control grassy and broadleaf weeds without any phytotoxic effect on wheat crop.

REFERENCES

Katara Pawan, Kumar Suresh, Rana SS and Chander Navell. 2013. Combination of pinoxaden with other herbicides against complex weed flora in wheat. *Indian Journal of Weed Science* **44**(4): 225-230.

Punia SS, Kamboj Baldev, Sharma SD, Yadav Ashok and Sangwan Naresh. 2006. Evaluation of carfentrazone-ethyl against *Convolvulus arvensis* L. and *Malwa parviflora* L. in wheat. *Indian Journal of Weed Sci*ence **38**(1&2): 5-8.

Shoeran Suman, Punia SS, Yadav Ashok and Singh Samunder. 2013. Bioefficacy of pinoxaden in combination with other herbicides against complex weed flora in wheat. *Indian Journal of Weed Science* **45**(2): 90-92.

Walia US and Singh B. 2006. Performance of triasulfuron and carfentrazone-ethyl against broad-leaf weeds. *Indian Journal Weed Science* **38**: 237-239.

Yadav DB, Punia SS, Yadav A, Singh S and Lal R. 2009. Pinoxaden: an alternate herbicide against little seed canary grass (*Phalaris minor*) in wheat (*Triticum aestivum*). *Indian Journal of Agronomy* **54** (4): 433-437.

Short communication

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Time of nitrogen application and weed management practices for increased production of wheat in Gujarat

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Wheat *(Triticum aestivum L.)* is an important cereal crop for a large number of countries in the world. It provides about 20% of total food calories for the human diet. It can be grown on a variety of soils but clay loam soil is most suitable (Hossain *et al.* 2006). In India, wheat stands second next to rice in area and production, but first in productivity among all the cereals. In Gujarat, area under wheat is about 12.07 lakh ha with total production of 28.97 lakh t and productivity of 2.40 t/ha.

Nitrogen is the key element for plant growth and development, as it is a constituent of chlorophyll. Applying nitrogen fertilizer is must to enhance production specially in non-legume crops, buts nitrogen management is the key approach in improving quality and productivity of wheat. Therefore, optimum use of nitrogen throughout the crop period is of vital importance to exploit the production potential of crop. Weeds have naturally good competitive ability, use more water and nutrients as compared to the crop plants and hence, weed management plays a vital role in boosting up wheat production. Nitrogen fertilization enhanced the weed population and growth and weeds may reduce the nitrogen use efficiency by the crop, particularly during the critical period of crop-weed competition. The use of herbicides is effective, if used at recommended dose Therefore, a study was done to see the effect of nitrogen and herbicide to increae the yield potential at middle gujrat conditions.

A field experiment was conducted during *Rabi* season of the year 2011-12 at the College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat). The treatments comprised combination of time of nitrogen application ($^{1}/_{2}$ as basal + $^{1}/_{2}$ at CRI; - $^{1}/_{2}$ as basal + $^{1}/_{4}$ at CRI + $^{1}/_{4}$ at FND; $^{1}/_{3}$ as basal + $^{1}/_{3}$ at CRI + $^{1}/_{3}$ at FND and weed management practices like pendimethalin 1 kg/ha (PE), metsulfuron-methyl 0.0004 kg/ha (PoE at 25-30 DAS), pendimethalin 1.0 kg/ha (PE) *fb* metsulfuron-methyl 0.0004 g/ha (PoE at 25-30 DAS), hand wedding at 20 and 40 DAS and weedy check. The experiment was laid out in a randomized block design (factorial) with fifteen treatment combinations replicated four times. Wheat vaiety '*GW-366*' was used in the experiment. Application of pendimethalin 1 kg/ha as pre sowing and metsulfuron-methyl 4 g/ha at 25 days after sowing was done as per treatment. Two hand weeding were carried out at 20 and 40 days after sowing as per treatment. The entire quantity of phosphorus (60 kg P_2O_5/ha) in the form of single super phosphate and nitrogen in the form of urea as per treatment were applied in opened furrows as basal application before sowing of wheat crop. The remaining half dose of nitrogen was top dressed at CRI and FND stage as per treatments. Remaining all agronomic practices were followed as per recommendations of the crop.

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Effect of nitrogen application

Application of nittrogen $^{1}/_{3}$ as basal + $^{1}/_{3}$ at CRI + $^{1}/_{3}$ at FND significantly recorded the highest grain yield (4,017 kg/ha) and straw yield (6,506 kg/ha, respectively) as compared to treatment $^{1}/_{2}$ as basal + $^{1}/_{2}$ at CRI. It might be due to the bold grains and vegetative growth resulted by application of nitrogen in split, which was reflected in higher grain and straw yields under this treatment. Similar results have been reported by Samra and Dhillon (2002).

Treatment $^{1}/_{3}$ as basal + $^{1}/_{3}$ at CRI + $^{1}/_{3}$ at FND minimized the monocot as well as dicot weed population and recorded significantly the lowest weed dry matter as compared to rest treatments at 25 and 50 DAS as well as at harvest (Table 1). Split application of nitrogen supply may have decreased N uptake of the weeds, which might have resulted in lower weed density and dry matter accumulation of weed species (Panwar *et al*. 1992).

Effect of weed management

Pendimethalin 1 kg/ha (PE) *fb* metsulfuron-methyl 0.004 kg/ha (PoE at 25-30 DAS) recorded sig-

Table 1. Effect of nitrogen and weed management practices on weed growth

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Weed count no./m^2 (monocot)		Weed count no./m^2 (dicot)		Weed dry matter (g/m^2)		Weed control efficiency (%)		Weed index (%)
			25 DAS	50 DAS	25 DAS	50 DAS	25 DAS	50 DAS	25 DAS	50 DAS	
Time of nitrogen application (T)											
$^1/_2$ as basal + $^1/_2$ at CRI	3.48	4.96	8.77 (87.4)	7.97 (73.0)	15.5 (281)	14.1 (229)	6.55 (43.4)	7.16 (51.8)	-	-	-
$^1/_2$ as basal + $^1/_4$ at CRI + $^1/_4$ at FND	3.78	5.99	8.62 (85.9)	7.95 (72.1)	15.7 (288)	13.6 (223)	4.75 (22.9)	5.51 (30.9)	-	-	-
$^1/_3$ as basal + $^1/_3$ at CRI + $^1/_3$ at FND (T_3)	4.01	6.51	8.62 (84.4)	7.90 (70.6)	15.8 (292)	13.4 (218)	2.89 (9.3)	4.05 (17.5)	-	-	-
LSD (P = 0.05)	0.17	0.43	NS	NS	NS	NS	0.17	0.16	-	-	-
Weed management (W)											
Pendimethalin	3.78	5.96	9.74 (95.4)	9.91 (98.4)	17.7 (315)	17.1 (292)	4.53 (22.9)	5.76 (34.9)	31.4	23.5	2.61
Metsulfuron-methyl	3.85	6.02	10.6 (113)	8.62 (74.5)	19.7 (388)	15.1 (228)	5.42 (30.6)	5.51 (31.9)	5.41	30.1	0.70
Pendimethalin *fb* metsulfuron-methyl	3.88	6.20	9.91 (98.4)	8.26 (68.3)	17.5 (309)	14.3 (205)	4.37 (20.5)	5.25 (29.2)	36.55	35.9	-
Pendimethalin *fb* metsulfuron-methyl	3.74	5.59	2.36 (7.8)	2.32 (6.2)	2.82 (8.00)	2.48 (8.4)	3.93 (19.5)	4.74 (25.2)	39.64	44.8	3.61
Weedy check	3.54	5.32	10.7 (114)	10.6 (112)	20.5 (419)	19.5 (382)	5.40 (32.3)	6.60 (45.6)	0.00	0.00	8.72
LSD (P = 0.05)	0.22	0.55	0.48	0.44	0.46	0.75	0.22	0.20	-	-	-

CRI= Crown root initiation stage; FND : First node development

nificantly higher grain yield than treatment weedy check but was at par with metsulfuron-methyl 0.0004 kg/ha (PoE at 25-30 DAS), pendimethalin 1.0 kg and hand wedding at 20 and 40 DAS. Treatment was also significantly superior in straw yield than hand wedding at 20 and 40 DAS and weedy check.but was at par with treatments pendimethalin 1.0 kg/ha and metsulfuron-methyl 0.0004 kg/ha (PoE at 25-30 DAS), respectively (Table 1). Weeds removal at early stage in the season reduces crop-weed competition at the lowest possible limit and provided almost weed free environment, which was probably the reason for higher yield. Significantly, minimum yield was found with treatment weedy check than rest of the treatments. It may be due to higher infestation of weeds in the plots resulted in strong competition of weeds with crop for growth factors (moisture, light, nutrients and space). The present results were in close conformity with the findings of Sharma *et al*. (1999). Significantly minimum weed count (monocot and dicot), the lowest weed dry matter, maximum WCE and maximum weed index at 20 and 40 DAS as well as at harvest were noted under hand weeding at 25 and 50 DAS (Table 2). Early removal of weed reduced the infestation of monocot, dicot types of weeds and it also benefitted the plant growth. The results substantiated the reports of Kurchania *et al.* 2000.

Significantly minimum weed dry matter was found with treatment combination $^1/_3$ as basal + $^1/_3$ at CRI + $^1/_3$ at FND and hand wedding at 25 and 50 DAS as well as at harvest of the crop (Table 2).

Conclusion

Treatment of $^1/_3$ as basal + $^1/_3$ at CRI + $^1/_3$ at FND recorded maximum grain yield, straw, grain, lower weed count, weed dry matter, weed index, higher weed control .Ttreatmentpendimethalin 1.0 kg/ha (PE) *fb* metsulfuron-methyl 0.004 kg/ha (PoE at 25-30 DAS) (3.88 t/ha) recorded the higher grain yield, straw yield. While, Treatment *of h*and weeding at 20 and 40 DAS recorded significantly minimum count, weed dry matter, weed index with higher weed control efficiency. Interaction of nitrogen and weed management practices were significant in respect of plant height at harvest weed dry matter at 25, 50 and at harvest.

Table 2. Interaction effect of time of nitrogen application and weed management practices at 25, 50 and at harvest

Treatment	weed dry matter at 25 DAS (g/m^2)			weed dry matter at 50 DAS (g/m^2)			weed dry matter at at harvest (g/m^2)		
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	6.33 (40.3)	4.61 (21.25)	2.66 (7.25)	7.19 (52.21)	5.75 (33.27)	4.35 (19.26)	14.39 (208.91)	9.96 (99.78)	7.53 (57.75)
W_2	6.79 (46.3)	5.31 (28.25)	4.15 (17.25)	6.94 (48.24)	5.48 (30.26)	4.10 (17.25)	13.87 (193.02)	9.49 (90.80)	7.11 (51.73)
W_3	5.72 (32.8)	4.50 (20.25)	2.90 (8.50)	6.64 (44.21)	5.39 (29.26)	3.71 (14.25)	13.28 (176.98)	9.33 (87.76)	6.43 (42.76)
W_4	6.26 (39.25)	4.15 (17.25)	1.37 (2.00)	6.64 (44.21)	4.66 (22.24)	2.91 (9.25)	12.05 (145.96)	4.00 (21.76)	1.57 (2.74)
W_5	7.63 (58.25)	5.20 (27.25)	3.35 (11.50)	8.37 (70.27)	6.25 (39.24)	5.17 (27.24)	16.73 (280.99)	10.83 (117.71)	8.96 (81.81)
LSD (P = 0.05)		0.19			0.35			0.86	

Figure in parenthesis indicate re-transformed value; All figures were subjected to transformed value (square root transformation); Tretment details of time of application (T_1, T_2, T_3) and weed managment (W_1 to W_5) as given in table 1

SUMMARY

A field experiment was conducted during the *Rabi* season of the year 2011-12 at Anand Agricultural University, Anand, Gujarat. The maximum grain yield, straw, grain, lower weed count , weed dry matter, weed index, higher weed control efficiency were obtained from treatment $^1/_3$ as basal + $^1/_3$ at CRI + $^1/_3$ at FND. Different weed management practices significantly influenced yields and weed parameters. The higher grain yield, straw yield were recorded from treatment pendimethalin 1.0kg/ha (PE) *fb* metsulfuron-methyl 0.004 kg/ha (PoE at 25-30 DAS) (3882 kg/ha). While, Treatment *of* hand weeding at 20 and 40 DAS recorded significantly minimum count, weed dry matter, weed index with higher weed control efficiency. The interaction effects time of nitrogen and weed management practices were significant in respect of plant height at harvest weed dry matter at 25, 50 and at harvest.

REFERENCES

Kurchania SP, Bhalla CS and Parandkar NR. 2000. Bio-efficiency of metsulfuron-methyl and 2, 4- D combination for broad-leaf weed control in wheat. *Indian Journal of Weed Science* **32**(1&2): 67-69.

Panwar RS, Malik RK and Malik RS. 1992. Effect of weedicides on weed control in wheat crop. *Indian Journal of Agronomy* **37**(2): 320-323.

Sharma BD, Nanwal RK and Panwar RS. 1999. Evaluation of herbicides for weed control in wheat (*Triticum aestivum*). *Indian Journal of Weed Science* **31**(1&2): 99-100.

Samara JS and Dhillon SS. 2002. Response of durum wheat (T*riticum durum* Desf.) to rate and time on nitrogen application under irrigated conditions. *Journal Research Punjab Agricultural University* **39**(1): 46-49.

Short communication

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Herbicides effect on weeds and yield of late sown wheat

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Key words: Clodinofop, Fenoxaprop, Late sown wheat, Weeds

Weeds are one of the prominent constraints in achieving potential yield of wheat. Wheat crop suffers with mix flora of weeds. The losses caused by weeds vary depending on the weed species, their abundance, crop management practices and environmental factors. It has been reported that with production of each kilogram of weed, one kilogram wheat grains are reduced (Chaudhary *et al.* 2008*)*. Herbicides are one of the major groups of pesticides which contribute to the increased and economical production of crops and minimize human toil in agriculture production. In this context, the continuous use of a particular herbicide for many years resulted in development of resistance against some weeds which happened in case of isoproturon (Malik and Singh 1995). It become necessary to access the application time, method and doses at micro farming levels which may varied according to soil type, micro climate, weed flora and its severity from their recommendations. Hence, an attempt was made to find out efficacy of alternate herbicides at different doses on wheat growth, yield and its associated weeds.

A field experiment was conducted during *Rabi* season 2010-11 at Agronomy Research Farm (26^0 47' N latitude, 82^0 12' E longitude and an altitude of 113 meters above mean sea level) of N. D. University of Agriculture and Technology, Kumarganj, Faizabad (UP). The soil was slightly alkaline in reaction (7.9 pH), low in organic carbon (0.32%), available nitrogen (180 kg/ha) and phosphorus (8 kg/ha), and medium in potassium (210 kg/ha) contents. The treatments consisted ten weed control treatments *viz*., fenoxaprop-p-ethyl 75 g/ha, fenoxaprop-p-ethyl 100 g/ha, fenoxaprop-p-ethyl120 g/ha, fenoxaprop-p-ethyl 150 g/ha, fenoxaprop-p-ethyl 200 g/ha, fenoxaprop-p-ethyl 240 g/ha, fenoxaprop-p-ethyl 120g/ha, flodinofop 60 g/ha, weedy check and weed free check in randomized complete block design with three replications. Wheat cultivar '*HUW 234*' was sown in second fortnight of December using seed rate 125 kg/ha in row 20 cm apart at 4-5 cm deep by seed drill. The crop was fertilized with NPK 120, 60, 40 kg/ha through urea, single super phosphate and muriate of potash, respectively. Four irrigations were applied as per need of the crop. Herbicides were applied as post-emergence at 35 days after sowing (DAS) with the help of manually operated knapsack sprayer fitted with flat fan nozzle using 600 liters of water per hectare. The recommended cultural practices and plant protection measures were adopted to raise the healthy crop. Observations on weeds and crop were taken as per standard procedure followed and being statistically analyzed to draw the reliable results and relevant data on weeds was subjected to square root transformation to normalize their distribution.

Wheat crop invaded with *Phalaris minor, Avena ludovaciana, Cynodon dactylon* in grassy; *Melilotus alba, Chenopodium album, Anagallis arvensis* under broad-leaved and *Cyperus rotundus* in sedges group. Results revealed that weed density affected significantly due to different weed control treatments (Table 1). Fenoxaprop applied at 240, 200 and 150 g/ha being equally effective between each other and recorded significantly less density of narrow-leaved weeds over rest of the treatments. However, lowest and highest density was recorded with weed free and weedy treatments. It was observed that the density of broad-leaved weeds were found significantly ineffective among all the test parameters because of fenoxaprop-p-ethyl and clodinofop are the narrow-leaf weed killer. Similarly, weed dry weight was also significantly lowest under these treatments. Application of fenoxaprop 75, 100, 120 g/ha and clodinofop 60 g/ha were found equally effective on same parameter. Selective bio-efficacy of same herbicides against narrow-leave weeds was also observed by Chhokar *et al*. (2007).

The maximum number of productive tillers recorded with Whipsuper fenoxaprop 120 g (370.0/m^2) followed by fenoxaprop 120 g (364.6/m^2), clodinofop 60 g and fenoxaprop 100 g/ha, but did not surpassed the spike count under weed free check (396.5 m^2). However, productive tillers were decreased at each successive increase in doses of fenoxaprop from 200

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Table 1. Effect of weed control treatments on weeds growth and performance of wheat

Treatment	Weed density (no./m^2) at 60 DAS	Weed dry weight (g/m^2) at 60 DAS	Productive tillers/m^2	Length of spike (cm)	Grain yield (t/ha)	B: C ratio	Nitrogen uptake (kg/ha)	
							Weeds	Wheat
Fenoxaprop 75 g/ha	13.0 (169.6)	10.2 (103.5)	319.8	7.59	3.53	1.85	3.43	74.9
Fenoxaprop 100 g/ha	12.9 (165.3)	9.9 (97.5)	322.1	7.95	3.72	1.93	3.53	77.8
Fenoxaprop 120 g/ha	12.8 (163.6)	9.0 (80.5)	364.6	8.88	4.06	2.14	2.10	88.0
Fenoxaprop 150 g/ha	12.8 (163.9)	8.5 (71.8)	318.6	7.87	3.62	1.76	3.70	75.4
Fenoxaprop 200 g/ha	12.6 (158.2)	7.8 (60.3)	281.6	7.50	3.39	1.50	4.62	69.2
Fenoxaprop 240 g/ha	12.7 (161.9)	7.0 (48.5)	278.4	6.75	3.33	1.39	3.31	67.3
Whipsuper (fenoxaprop) 120 g/ha	12.9 (165.3)	9.2 (84.1)	370.0	8.91	4.09	2.17	2.01	88.4
Clodinofop 60 g/ha	12.7 (161.1)	9.6 (91.7)	358.8	8.81	3.76	2.13	2.12	83.7
Weedy check	15.5 (239.9)	11.6 (134.0)	197.3	6.11	2.89	1.40	6.54	58.1
Weed free check	0.7 (0.0)	0.7 (0.0)	396.5	9.46	4.38	1.97	0.00	95.4
LSD (P=0.05)	2.50	0.91	53.9	1.04	0.35	-	0.56	6.64

Data are subjected to square root transformation; values in the parentheses are original values

to 240 g/ha. It might be due to the phytotoxic effect of higher dose of fenoxaprop on wheat crop and it has inverse relationship with weed control parameters, crop growth, yield attributes and grain yield. These results were in conformity with the work done by Malik *et al.* (2005). Herbicides applied at lower doses had measured significantly longest spike than higher doses of fenoxaprop at 200 and 240 g/ha. All weed control practices were significantly influenced grain yield in comparison to uncontrolled weeds during crop period. Whipsuper (fenoxaprop 120 g), fenoxaprop 100 and 120 g and clodinofop 60 g/ha being at par and also recorded statistically higher grain yield over rest of chemical weed control treatments. These findings are well corroborated with the results obtained by Yadav *et al.* (2009). Similarly, these grain yield enhancing measures are also observed to be more remunerative by gaining higher benefit: cost ratio except repetitive manual weeding. The nitrogen depletion by crop is directly correlated with grain yield produced by the treatments and inversely associated with fenoxaprop at higher doses. However, weeds under whipsuper (fenoxaprop) at 120 g/ha treatment depleted significantly lesser nitrogen (2.01 kg/ha) followed by rest of treatments except season long weedy conditions (6.54 kg/ha).

SUMMARY

A field experiment was conducted during *Rabi* season of 2010-11 at Faizabad to assess the bio-efficacy of fenoxaprop and formulation of fenoxaprop available as Wipsuper in the market at various doses and clodinofop on weeds and productivity of late sown wheat. Fenoxaprop at higher doses effectively suppressed weeds and produced significantly lowest weed dry weight but it did not able to enhance nitrogen removal by crop as at lower doses. Post-emergence application of Whipsuper (fenoxaprop) 120 g, fenoxaprop 100 and 120 g and clodinofop 60 g/ha in late sown wheat eliminates crop weed competition at tillering and grant growth period which ultimately provides congenial conditions to crop for better harnessing of available crop growth resources and produced profitable grain yields.

REFERENCES

Chaudhary SU, Hussain M, Ali MA and Iqbal J. 2008. Effect of weed competition period on yield and yield components of wheat. *Journal of Agricultural Research* **46**: 47-53

Chhokar RS, Sharma RK, Pundir AK and Singh RK. 2007. Evaluation of herbicides for control of *Rumex dentatus, Convolvulus arvensis* and *Malva parviflora. Indian Journal of Weed Science* **39**: 214-218.

Malik RK and Samunder Singh. 1995. Little seed canary grass (*Phalaris minor*) resistance to isoproturon in India. *Weed Technology* **9**: 419-425.

Malik RS, Yadav A, Malik RS and Singh S. 2005. Efficacy of clodinofop, fenoxaprop, sulfosulfuron and triasulfuron alone and of tank mixture against weeds in wheat. *Indian Journal of Weed Science* **37**(3&4): 180-183.

Yadav DB, Yadav Ashok, Singh S and Roshan Lal. 2009. Compatibility of fenoxaprop-p-ethyl with confentrazone-ethyl metsulfuron-methyl and 2,4-D for controlling complex weeds of wheat. *Indian Journal of Weed Science* **37**(3&4): 180-183.

Short communication

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Ragweed emerging a major host for the cotton mealy bug in Pakistan

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Key words: Alternate host, Diseases, *Parthenium hysterophorus*, Pests, *Phenacoccus solenopsis*

Parthenium hysterophorus is an invasive weed of global significance that has become a major weed in sub-continent and many other parts of the world. *Parthenium* has been reported to be a significant weed of rangelands, crops, a disrupter of biodiversity in natural ecosystems and a health hazard to people and livestock (Adkins *et al*. 2010). The indirect impacts of *Parthenium* weed on agricultural production are also significant. *Parthenium* can also cause indirect losses to crop production by acting as a secondary host to a number of important crop pests and diseases, for example, common hairy caterpillar (*Diacrisia obliqua* Walk.) *Xanthomonas campestris* pv. *phaseoli* and tobacco streak virus. A list of economically important pests and diseases reported on *Parthenium* weed is presented (Table 1).

In agricultural ecosystems of Pakistan, *Parthenium* is commonly found growing along the water courses, filed verges and wastelands and abandoned agricultural fields. The weed is now slowly but

Table 1. Pests and diseases that are known to use *Parthenium* weed as an alternate host

Agent	Main host(s)	Reference(s)
Insects		
Pseudoheteronyx sp.	Sunflower	Robertson and Kettle (1994)
Liriomyza trifolii Burgess	Bell pepper	Chandler and Chandler (1988)
Diacrisia obliqua Walker.	Multiple crops	Remadevi and Sevaramakirishnan (1996)
Phenacoccus solenopsis Tinsley	Multiple crops	Arif *et al*. (2009)
Aphis fabae Scopoli	Black bean	Rajulu *et al*. (1976)
Fungi		
Myrothecium roridum Tode ex Fr. Colletotrichum gloeosporoides (Penz.) Sacc.	Crops and trees	Pandey *et al.* (1990)
Fusarium oxysporum Schlect. Fusarium monoliforme Sheld.	Crops and trees	Pandey *et al.* (1991)
Sclerotium rolfsii Sacc.	Multiple crops	Siddaramaiah *et al*. (1984)
Alternaria zinniae M. B. Ellis	Zinnia	Sharma and Gupta (1998)
Rhizoctonia solani Kuhn	Many crops	Kumar *et al.* (1979)
Bacteria		
Xanthomonas campestris pv. Phaseoli	Bean	Ovies and Larrinaga (1988)
Pseudomonas solanacearum E. F. Smith	Multiple crops	Kishun and Chand (1987)
Viruses		
Tomato leaf curl virus	Tomato	Govindappa *et al.*(2005)
		Sastry (1984)
Potato virus X and Y	Potato	Cordero (1983)
Tobacco streak virus (TSV)	Cotton	Ahmed *et al.* (2003)
	Sunflower	Basappa (2005)
	Mungbean	Sharman *et al.* (2009)
	Groundnut	Sharman *et al.* (2009)
Tobacco leaf curl virus	Tobacco	Swanson *et al.*(1998), Reddy *et al.* (2002)
Phytoplasma		
Phyllody disease	Black bean	Taye *et al.* (2002)
Brinjal little leaf	Brinjal	Singh and Singh (1998)

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progressively moving inside the major crops such as, wheat, rice (direct seeded) sugarcane and maize (Shabbir *et al*. 2012). Its year-round occurrence provides an excellent opportunity for many agricultural pests and diseases to survive in the unfavorable conditions. In survey to document the distribution of *Parthenium* weed in the Punjab, province of Pakishtan in 2009-10, an exotic mealy bug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) was consistently found attacking *Parthenium* plants growing in wastelands of the districts Lahore, Kasur, Pakpatan, Khanewal, Okara and Sahiwal.

Phenacoccus solenopsis is a serious pest in many parts of the world where it causes serious damage to number of major crops fruits and vegetables. Cotton (*Gossypium hirsutum* L.) is major cash crop mostly grown southern Punjab and the Sind provinces and it provides fiber, food and fuel and earns foreign exchange for the country. It is estimated that *P. solenopsis* had infested 45,000 sq. km area across Pakistan, especially in the Punjab and Sindh provinces (Hodgson *et al*. 2008). In a survey to document the alternate hosts, Arif *et al.* (2009) listed *Parthenium* weed as one of the 154 host plants for *P. solenopsis* in cotton agroecosytem of the Punjab. Already in India, *Parthenium* weed has been reported as important alternate host for *P. solenopsis* and this weed has been listed among very few hosts with extreme severity of *P. solenopsis* during crop and off seasons in all zones of cotton (Vennila *et al*. 2011). *Phenacoccus solenopsis* multiplies on weedy host plants and moves onto crop plants during the season.

Parthenium is spreading very fast in Pakistan (Shabbir *et al.* 2012), and its presence in cotton growing areas, poses a serious threat to the cotton crop. In Pakistan, *P. solenopsis* attack is increasing, and it could result in an epidemic in the cotton-growing areas if unchecked. It is recommended that alternate hosts of this pest especially the preferred *Parthenium* weed should be managed to stop its further spread of both the invasive *Parthenium* weed and *P. solenopsis* to minimize the losses.

SUMMARY

Parthenium is an alien invasive species spreading very fast in natural and agricultural ecosystems of Pakistan. Besides having direct negative effects on many field crops and other economically important plants, this weed has also been reported to be an alternate host of a number of agricultural pests and diseases. This paper reports *Parthenium* weed being as an emerging host for cotton mealy bug in Pakistan. Efforts were needed to remove *Parthenium* weed from cotton growing belt to minimize the damages caused by this pest to cotton crop in the season.

REFERENCES

Adkins SW, O'Donnell C, Khan N, Nguyen TL, Shabbir A and Dhileepan K. 2010. *Parthenium* weed (*Parthenium hysterophorus* L.) research in Australia: New management possibilities, pp.120-123. In: *Proceedings of the 17th Australasian Weeds Conference*, New Zealand. Christchurch, New Zealand. New

Ahmed W, Butt TB, Ihsan J and Rehman A. 2003. Natural occurrence of tobacco streak virus in cotton in Pakistan and screening for its resistant sources. *Pakistan Journal of Botany* **35**: 401-408.

Arif MI, Rafiq M and Ghaffar A. 2009. Host plants of cotton mealy bug (*Phenacoccus solenopsis*): A new menace to cotton agroecosystem of Punjab, Pakistan. *International Journal of Agriculture and Biology* **11**: 163-167.

Basappa H. 2005. *Parthenium,* an alternate host of sunflower necrosis disease and thrips, pp. 83-86. In: *Second International Conference on Parthenium management,* (Eds. Ramachandra Prasad TV, Nanjappa HV, R. Devendra) University of Agricultural Sciences, Bangalore, India,

Chandler LD and Chandler JM. 1988. Comparative host suitability of bell pepper and selected weed species for *Liriomyza trifolii* (Burgess). *Southwestern Entomologist* **13:** 137-146.

Cordero M. 1983. *Parthenium hysterophorus* (bitter broom), undesirable plant, natural reservoir of potato viruses X and Y. Ciencia y Tecnica en la Agricultura, Hortalizas, Papa, Granos y Fibras **2**: 23-32.

Govindappa MR, Shankarappa KS, Rangaswamy KT and Muniyappa V. 2005. In vitro evaluation of plant protection chemicals for compatibility with potential bioagent *Paecilomyces farinosus* of whitefly (*Bemisia tabaci*), an insect vector of tomato leaf curl virus disease. *Environment and Ecology* **23**: 517-522.

Hegde BA and Patil TM. 1979. Mealybug attacking *Parthenium hysterophorus* linn. *Current Science* **48**: 179-180.

Hodgson CJ, Abbas G, Arif MJ, Saeed S, Karar H. 2008. *Phenacoccus solenopsis* Tinsley (Sternorrhyncha: Coccoidea: Pseudococcidae), an invasive mealybug damaging cotton in Pakistan and India, with a discussion on seasonal morphological variation. *Zootaxa* **1913**: 1-35.

Kishun R and Chand R. 1987. New collateral hosts for *Pseudomonas solanacearum*. *Indian Journal of Mycology and Plant Pathology* **17:** 237.

Kumar, S., Jayaraj, S. Muthukrishnan, T.S. 1979. Natural enemies of *Parthenium hysterophorus* Linn. *Journal of Entomological Research* **3**(1), 32-35.

Ovies J and Larrinaga L. 1988. Transmission of *Xanthomonas campestris* pv. *phaseoli* by a wild host. *Ciencia y Tecnica en la Agricultura, Proteccion de Plantas* **11**: 23-30.

Pandey AK, Hasija SK and Rajak RC. 1990. *Myrothecium roridum* Tode ex Fr. a new pathogen of *Parthenium hysterophorus* L. with biocontrol potential. *National Academy Science Letters* **13:** 369-370.

Pandey AK, Luka RS, Hasija SK and Rajak RC. 1991. Pathogenicity of some fungi to *Parthenium*, an obnoxious weed in Madhya Pradesh. *Journal of Biological Control* **5** :113-115.

Rajulu GS, Gowri N and Perumal SS. 1976. Biological control for the pernicious weed *Parthenium hysterophorus* Linn. *Current Science* **45**: 624-625.

Reddy AS, Rao RDVJP, Thirumala-Devi K, Reddy SV, Mayo MA, Roberts I, Satyanarayana T, Subramaniam K and Reddy DVR. 2002. Occurrence of Tobacco streak virus on peanut (*Arachis hypogaea*) in India. *Plant Disease* **86**: 73-178.

Remadevi OK and Sivaramakrishnan VR. 1996. Biomass utilisation by *Diacrisia obliqua* Walker feeding on *Tectona grandis* Linn. F. and *Parthenium hysterophorus* L. pp. 441-447. In:*Impact of diseases and insect pests in tropical forests.* Proceedings of the IUFRO Symposium, Peechi, India, 23-26 November 1993.

Robertson LN and Kettle BA. 1994. Biology of *Pseudoheteronyx* sp. (Coleoptera: Scarabaeidae) on the Central Highlands of Queensland. *Journal of the Australian Entomological Society* **33**: 181-184.

Sastry KS. 1984. Strains of tomato leaf curl virus and its perpetuation under field conditions. *Journal of Turkish Phytopathology* **13**: 87-90.

Sharma DD and Gupta AK. 1998. *Alternaria zinniae* on *Parthenium hysterophorus*. *EPPO Bulletin* **28:** 217.

Shabbir A, Dhileepan K and Adkins SW. 2012. Spread of *Parthenium* weed and its biological control agent in the Punjab, Pakistan. *Pakistan Journal of Weed Science Research* **18:** 581-588.

Sharman M, Persley DM and Thomas JE. 2009. Distribution in Australia and seed transmission of Tobacco streak virus in *Parthenium hysterophorus*. *Plant Disease* **93**: 708-712.

Siddaramaiah AL, Narendrappa T and Shivalingaradhya MV. 1984. A new collar rot disease of *Parthenium* from India. *Plant Pathology Newsletter* **2**: 11.

Singh BR and Singh AK. 1998. Occurrence of two MLO diseases on Congress grass and their management in Uttar Pradesh. *International Journal of Tropical Plant Diseases* **16**: 55-59.

Swanson MM, Valand GB, Muniyappa V and Harrison BD. 1998. Serological detection and antigenic variation of two whitefly-transmitted geminiviruses: tobacco leaf curl and croton yellow vein mosaic viruses. *Annals of Applied Biology* **132**: 427-435.

Taye T, Gossmann M, Einhorn G, Buttner C, Metz R and Abate D. 2002. The potential of pathogens as biological control of *Parthenium* weed (*Parthenium hysterophorus* L.) in Ethiopia. *Mededelingen - Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen, Universiteit Gent* **67**: 409-420.

Short communication

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Integrated weed management in turmeric

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Turmeric is one of the important spice crop grown in India in an area of 1.49 lakh hectares with a production of 5.27 tones. India is leading in turmeric cultivation contributing 70% production but productivity is much lower. Weed competition is one of the limiting factors for low yield of crop. Due to improper weed management, 30-70% yield losses have been reported (Krishnamurty and Ayyaswamy 2000). Turmeric is a long durational crop (more than 280 days), therefore pre-emergence application of herbicides alone does not control weeds throughout critical crop weed competition period of the crop and needs an integration of post-emergence application of herbicide or inter-culture operation in combination with pre-emergence herbicide application. Hence a field experiment was carried out to suggest a suitable integrated weed management in turmeric.

The experiment was carried out during 2012-13 in randomized block design with three replications on medium black soil with slightly alkaline in reaction (pH 8.1), low in nitrogen (212 kg/ha), medium in phosphorus (15.6 kg/ha) and high in potassium (578 kg/ha) content at Weed Science Research Station, V Naik Marathwada Krishi Vidyapeeth,Parbhani, which falls within 19^0 16' N latitude and 76^0 47' E longitude. The turmeric variety '*Selum*' was planted on raised beds at 90 x 30 :120 cm spacing on 19 June 2012. The recommended dose of FYM at 10 t/ha and 200:150:150 kg/ha NPK was applied in equal three splits at planting, 60 and 120 days after planting. The treatments were metribuzin 0.7 kg/ha PE *fb* two hoeings, metribuzin 0.7 kg/ha PE *fb* fenoxaprop 67 g/ha + metsulfuron 4g/ha POE , metribuzin 0.7 kg/ha PE *fb* straw mulch 10 t/ha *fb* one HW, pendimethalin 0.7 kg/ha PE *fb* two hoeings, pendimethalin 0.7 kg/ha PE *fb* fenoxaprop 67 g/ha + metsulfuron 4g/ha POE , pendimethalin 0.7 kg/ha PE *fb* straw mulch 10 t/ha *fb* one HW, atrazine 0.75 kg/ha PE *fb* fenoxaprop 67 g/ha + metsulfuron 4g/ha POE , atrazine 0.75 kg/ha PE *fb* straw mulch 10 t/ha *fb* one HW, weed free and weedy check. The weed count was taken at 30 and 60 DAS, in addition to this weed dry matter was also recorded and used for calculating weed control efficiency in each treatment. The quadrant (1 x 1 m size) was used for taking the observations on weeds. The herbicides were applied as per treatments, using a spray volume of 500 litres/ha for pre-emergence and 300 litres/ha for post emergence with knapsack sprayer with flat fan nozzle. The economics was worked out based on cost of cultivation ` 79,000/ha and average sale price of raw turmeric ` 20,000/t.

The dominant weed flora of turmeric experimental plot was *Acalapha indica, Euphorbia geniculata, Parthenium hysterophorus, Digeria arvensis* (among broad-leaved weeds), *Cynodon dactylon, Brachiria eraciformis* (among grassy weeds) and *Cyprus rotundus* (sedge).

All the weed control treatments significantly reduced dry weight of weeds and weed control efficiency significantly over weedy check (Table 1). Among the various treatments, metribuzin 0.7 kg/ha PE *fb* straw mulch 10 t/ha *fb* one HW recorded lowest dry weight of weeds (4.1, 7.5 and 10.1, 18.6 for grassy and BLW, respectively) and highest WCE (68 and 75 %) at both the observations (30 and 60 DAS) as compared to all other treatments.

No crop injury was observed with the pre-emergence herbicide application under study, however post-emergence application of fenoxaprop + metsulfuron 67 + 4 g/ha caused injury (50%) to turmeric. Rhizome weight, finger weight and number per plant and fresh rhizome yield were significantly influenced by the weed control treatments (Table 1). Among the various treatments, metribuzin 0.7 kg/ha PE *fb* straw mulch 10 t/ha *fb* one HW recorded significantly highest fresh rhizome yield (12.16 t/ha) as compared to other treatments except the treatments included the straw mulch application. Unweeded check recorded the significantly lowest fresh rhizome yield (3.02 t/ha) with a yield loss of 80%. Similar results were also reported by Avilkumar *et al.* (2000) and Ratnum *et al.* (2012).

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Table 1. Rhizome yield, dry weed weight and weed control efficiency in turmeric as influenced by weed control treatments

Treatment	Fresh rhizome yield (t/ha)	Dry weed weight (g/m^2)				Weed control efficiency (%)		Net returns ($x10^3$ `/ha)	B:C ratio
		Grassy		Broad- leaved					
		30	60	30	60	30	60		
Metribuzin 0.7 kg/ha PE *fb* two hoeings	10.16	4.7	8.9	14.6	14.1	60	65	120.64	1.46
Metribuzin 0.7 kg/ha PE fb fenoxaprop 67 g/ha + metsulfuron 4g/ha POE	8.11	4.1	7.5	10.1	18.6	62	70	89.65	0.99
Metribuzin 0.7 kg/ha PE *fb* straw mulch 10 t/ha *fb* one HW	12.16	2.0	6.1	13.2	18.2	68	75	144.63	1.47
Pendimethalin 0.7 kg/ha PE *fb* two hoeings	9.75	5.1	6.5	20.4	21.8	55	58	111.76	1.34
Pendimethalin 0.7 kg/ha PE *fb* fenoxaprop 67 g/ha + metsulfuron 4g/ha POE	8.06	3.1	3.8	18.2	26.4	64	71	78.85	0.95
Pendimethalin 0.7 kg/ha PE *fb* straw mulch 10 t/ha *fb* one HW	10.28	5.7	8.4	16.1	20.8	68	64	105.88	1.06
Attrazine 0.75 kg/ha PE *fb* fenoxaprop 67 g/ha + metsulfuron 4g/ha POE	7.66	3.1	5.3	10.1	14.3	56	62	71.56	0.87
Attrazine 0.75 kg/ha PE *fb* straw mulch 10 t/ha *fb* one HW	9.74	5.1	6.0	8.1	14.6	65	72	97.88	0.96
Weed free	109.5	3.2	5.0	15.2	11.2	70	78	118.4	1.18
Weedy Check.	30.20	6.1	7.0	18.2	25.1	-	-	19.10	0.24
LSD (P=0.05)	27.95	2.01	4.85	5.16	5.80	-	-	53.81	-

Among the weed management treatments highest net monitory returns (` 1,44,630/ha) and B:C ratio (1.47) were recorded with metribuzin 0.7 kg/ha PE *fb* straw mulch 10 t/ha *fb* one HW owing to lower weed growth and highest turmeric yield.

SUMMARY

A field experiment was carried out during 2012-13 in randomized block design with three replications at Weed Science Research Station, VNMKV, Parbhani with eight treatments. Results showed that metribuzin 0.7 kg/ha PE *fb* straw mulch 10 t/ha *fb* one HW recorded lowest dry weight of weeds, highest weed control efficiency, fresh rhizome yield (12.16 t/ha) net monitory returns (` 1,44,630/ha) and B:C ratio (1.47) as compared to other treatments .

REFERENCES

Avilkumar K and Reddy MD. 2000. Integrated weed management in maize + turmeric intercropping system. *Indian Journal of Weed Science* **32**(1&2): 59-62.

Krishnamurty VV and Ayyaswamy M. 2000. Effect of herbicides on yield of turmeric. *Spice India* **13**: 9-11.

Ratnum M, Rao AS and Reddy TY. 2012. Integrated weed management in turmeric (*Curcuma longa*) *Indian Journal of Agronomy* **57**(1): 82-84.

Short communication

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Natural incidence of agromyzid fly on broomrape

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Key words: Biocontrol, Broomrape, Egg plant, *Orobanche crenata*, *Phytomyza orobanchia*

Broomrapes (*Orobanche* spp.) are total root parasitic flowering plants that occur in many agriculturally important crops in India. The most important and common species found in India are *O. crenata, O. ramosa* and *O. aegyptiaca* on solaneceous vegetables, tomato, brinjal and potato and *O. cernua* on mustard and tobacco. During survey conducted by the authors in the Billua village (26^{0}02'59,32"N; 78^{0}17'00.03"E) of Gwalior district in Madhya Pradesh, India during January 2013, brinjal (*Solanum melongena*) with chili pepper (*Capsicum annuum*) as inter crop, were found infested by *Orobanche crenata.* In the same field flowering stalks of some *O. crenata* were found in various stages of drying, while the host was still healthy and alive. Closer observation of the uprooted stalks revealed the bore holes and extensive tunnels with tiny brown pupae and small white maggots, feeding on the capsules, succulent stalk and tubercles. The field was then marked, number of infected *O. crenata* stalks counted (Table 1) and collected in polythene bags for detailed studies in the laboratory.

The insect species damaging *O. crenata* was identified as *Phytomyza* sp. based on their morphology. The insect specimens were sent to National Bureau of Agriculturally Important Insects, Bengaluru, India for identification and accordingly the insects were identified as *Phytomyza orobanchia* Kal. The DNA sequences of cytochrome c oxidase subunit-I (cox1) gene of the insects were submitted in the gene bank accession p. no. KC732453.1, p. 658 (Rakshit *et al.* 2013).

The samples were brought to the laboratory in DWSR, stored in incubator at 26±0.5 ^{0}C. Observations under stereo binocular microscope of the collected specimens revealed that the maggots are white in colour, without legs and did not have a head capsule. Internal skeleton was visible through the transparent body wall and there were no chewing mouthparts on the head region. The adults emerged out at various periods depending upon the stage of the larvae or pupae. Proportion of emergence of adults was more from the soft and succulent flowering stalks (28/43) when compared to the hard tubercles (15/43). Per cent incidence of *P. orobancha* in the infested field was 46% while the per cent incidence of the weed in the field was 27.5% (Table 1). Similar observations of variable emergence of adults from different parts of *Orobanche* was also reported by Abu-shall and Amany (2012). The adult flies are generally black in colour with yellow borders to the abdomen segments.

Attempts by the authors to collect the insects from the same fields during next year (2014) were not successful because of the cultivation of green chilies alone in the field. It has been observed that natural infestation of *Orobanche* spp. by *P. orobanchia* is usually not sufficient to cause significant reduction in the populations of *Orobanche* (Klein and Kroschel 2002). However, it is possible to collect the *Orobanche* stalks from areas where *P. orobanchia* occur naturally and the emerging adults can be released in the infested fields as biocontrol agent for management of *Orobanche* as on date there are no effective management strategies for *Orobanche* control (Parker 2012), hence the weed require complimentary integration of all available techniques and strategies for its management in different crops. Biological control is effective and is easy to combine with other control methods and it could be part of an integrated *Orobanche* man-

Table 1. Incidence of *P. orobancha* in the infested field

Total number of brinjal plants	235
Average number of stalks/plant	4
Percent incidence of *Orobanche crenata*	27.5
Percent incidence of *P. orobanchia*	46
Larvae/pupae in spike	48%
Larvae/pupae in flowering stalk	38%
Larvae/pupae in tubercle	14%
Infested *O. crenata* plants incubated in the lab	25
Total no. of adults emerged	43
No. of adults emerged from the flowering stalks	28
No. of adults emerged from the tubercles	15

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agement system. Thus in the case of *P. orobanchia*, there is a double advantage of hand weeding the stalks of *Orobanche* from infested fields and using them for rearing the flies and then releasing the adult flies in new areas (Klein and Kroschel 2002). Further since the *P. orobanchia* is capable of reducing the seed production of *Orobanche* (Linke *et al.* 1990), it can be effective in reducing the seed bank for the next cropping season. Compatible herbicides can be screened for use along with the release of these flies. *P. orobanchia* is suitable for both classical and inundative approaches of biocontrol. However their ecological requirements have to be thoroughly studied in order to use them more effectively.

Further it is essential to create awareness among the farmers about the dangers of unscrupulous spraying of insecticides that may destroy the natural incidence of these friendly insects.

SUMMARY

Natural incidence of the oligophagous fly *Phytomyza orobanchie* was observed on *Orobanche crenata* in brinjal (egg plant: *Solanum melongena*) in the farmers' field in Central India during a survey in January 2013. This natural incidence indicatesd that the bioagent is now established in India. The bioagent has been submitted to gene bank accession (No. KC732453.1, p. 658). It was concluded that if more intensive surveys are conducted in the *Orobanche* infested areas, there may be chances for more areas to be indentified and this insect may be used in the integrated management of *Orobanche*.

REFERENCES

Abu-shall and Amany MH. 2012. Effect of laboratory preservation of *Phytomyza orobanchia* (Diptera: Agromyzidae) pupae in broomrape shoots on emergence and viability of resultant adults. *Egyptian Journal of Biological Pest Control* **22:** 121-126.

Kaltenbach JH. 1864. Die deutschen Phytophagen aus der Klasse der Insekten (M-P). *Verhandlungen des naturhistorischen Vereins der preussischen Rheinlande and Westfalens* **21**: 228-404.

Klein O and Kroschel J. 2002. Biological control of *Orobanche* sp. with *Phytomyza orobanchia*: a review. *Bio-control* **47**: 245-277.

Linke K Vorlaender C and Saxena MC. 1990. Occurrence and impact of *Phytomyza orobanchia* (Diptera: Agromyzidae) on *Orobanche crenata* (Orobanchaceae) in Syria. *Entomophaga* **35:** 633-639.

Manjunath TM and Nagarkatti S. 1977. Natural enemies of *Orobanche* in India and possibilities of its biological control. *Technical Bulletin of the Commonwealth Institute of Biological Control* **18:** 75-83.

Rakshit O, Jalali SK and Kannan C. 2013. *Phytomyza orobanchia* voucher AIN26002MP001 cytochrome c oxidase subunit I (cox1) gene, partial cds; mitochondrial. Gen Bank accession no. KC732453.1, p. 658.

Short communication

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Autecology of blood grass in wetland rice ecosystem

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Key words: Autoecology, Blood grass, *Isachne miliacea*, Rice, Wetland

Autecological studies envisage the study of an organism in its environment. A thorough knowledge about the weeds in terms of its growth and development, propagation, adaptation, response to various stimuli or resources in a particular habitat in association with crops is highly essential before adopting any control measures (Duary *et al.* 2000). A careful consideration of these facts in relation to different crop management practices may provide a suitable strategy for suppression of the weeds. However, there is a considerable lack of information on the biology and ecology of many weeds occurring in rice in the tropics (Moody 1980). Development of an appropriate and effective weed management programme is dependent on the sound knowledge of weed biology (Rao 2000). Such studies are important in saving the precious crops from devastation. *Isachne miliacea* Roth ex Roemet Schult is one such troublesome dominant grass weed found in the wetland rice ecosystem of Thiruvananthapuram district, Kerala state. The weed spreads mainly by seed and rooted portions of the stem and is hard to eradicate once established. A sound knowledge of biology of *I. miliacea* will help to develop strategies for its efficient and eco-friendly management. With this background information, an investigation was carried out to examine the growth and developmental pattern of blood grass (*I. miliacea*) as influenced by nutrient management and spacing of associated rice with an approach to assess the possibility for managing them through agronomic manipulations.

The field experiments were conducted during the first and second crop seasons of 2010 in the wetlands of the Instructional farm attached to College of Agriculture, Vellayani located at 8.5°N latitude and 76.9°E longitude and at an altitude of 29 m above mean sea level (MSL). The rice variety used for the experiment was '*PTB 52 (Aiswarya)*' released from Rice Research Station, Moncompu. The experimental area was puddled twice and leveled. Weeds and stubbles were removed by hand picking. Five blocks with 12 treatment combinations each were laid out in strip plot design. The plots were separated with channels of 60 cm width and each block was separated with channels of 1 m width. The treatments included N_1-NPK 90:45:45 kg/ha with 100% N as chemical fertilizer (POP), N_2-NPK 90:45:45 kg/ha with 75% N as chemical fertilizer and 25% N as organic, N_3- NPK 112.5:56.25:56.25 kg/ha with 100% N as chemical fertilizer, N_4-NPK 112.5:56.25:56.25 kg/hawith 75% N as chemical fertilizer and 25% N as organic under three type of spacing S_1-15 x 15, S_2-20 x 15, S_3-20 x 20 cm(Table 1). All the treatments uniformly received FYM 5 t/ha as per package of practices recommendations for rice, Kerala Agricultural University. Periodic observations on general growth habit, floral characters, seed production and days taken for germination and 50% flowering were taken from 10 sample plants each during the entire crop season and the averages were worked out and were statistically analyzed.

I. miliacea was found to be widely creeping prostrate plant, branching and rooting at nodes with slender culms. The leaves were small, hispid with sparingly hairy sheath. The ligule was a ring of hairs. Average leaf size was 2.0 cm x 4.5 mm. The shoot length of the weed was vary from 23.4 to 25.6 cm with an average of 24.5 cm. The root length varied from 12.2 to 13.8 cm and the average plant spread was 62.2 cm. Inflorescence emergence was noticed from 35 days of transplanting of rice crop. The spikelets were in pairs, unequally stalked and purplish. These biometric characters were in conformity with earlier reports (Ravi and Mohanan 2002). It was observed that the perennial weed formed large clumps with mat like root system which in the rice field created problems during weeding. Its density increased as rice matured thus making competition more severe at critical periods. Weed propagation was both through seeds and rooted stem bits.

The results revealed that the growth and development of *I. miliacea* was significantly influenced by the management practices for the associated rice crop. The main effect of nutrient management and plant density of rice crop and their interaction effects were

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significant in deciding the shoot and root length of the weed plant. The general trend was that higher dose of NPK applied as chemical fertilizers only along with wider spacing increased all the vegetative parameters (shoot/root length and plant spread) of the weed throughout the study (Table 1). Several other workers have confirmed that addition of higher dose of fertilizers permitted the luxuriant growth of crops and weeds alike almost all the year round (Zimdahl 1980).

Table 1. Shoot length and root length of *I. miliacea* as influenced by nutrient management and plant density of rice

Treatment	First season		Second season	
	Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)
N_1S_1	23.4	12.2	23.4	12.2
N_1S_2	23.8	12.5	23.8	12.5
N_1S_3	24.3	13.3	24.1	13.3
N_2S_1	24.2	12.2	24.2	12.3
N_2S_2	24.3	12.4	24.3	12.4
N_2S_3	24.4	12.8	24.6	12.8
N_3S_1	25.1	13.8	25.0	13.6
N_3S_2	25.3	13.7	25.2	13.7
N_3S_3	25.3	13.8	25.3	13.7
N_4S_1	25.1	12.7	24.4	12.5
N_4S_2	25.1	12.8	24.4	12.8
N_4S_3	25.6	13.4	24.5	13.4
LSD P=0.05)	0.63	0.14	0.52	0.21

The data indicated that the nutrient levels and plant spacing for the rice crop had significant influence on the reproduction characteristics of the grass weed. During both the crop seasons *I. miliacea* growing in rice fields treated with 100 per cent NPK with 25 per cent organic substitution (N_2) and plants in rice crop planted at wider spacing (P_3) recorded delayed flowering but produced more seeds/panicle when compared to the other treatments and the difference was statistically significant (Table 2). Though there was variation among the interaction effect ,no distinct pattern could be elucidated.

SUMMARY

Based on the data on the effect of nutrient management and crop spacing on the growth and development of *I. miliacea*, it could be elucidated that application of enhanced nutrients exclusively as chemical fertilizers in combination with wider spacing stimulated growth and vigour of the weed. Hence an integrated approach in nutrient management is suggested for efficient and economic management of the weed. By altering nutrient management and adjusting the plant population, the competitive ability and productivity of rice crop can be improved and weed management made more efficient and economic. Considering the practical importance of the study, detailed investigation in similar lines needs to be conducted on such major weeds for the entire state under all systems of rice cultivation including upland rice.

Table 2. Growth and yield attributes of *I. miliacea* as influenced by nutrient management and plant density of rice

Treatment	First season			Second season		
	Plant spread (cm)	Number of days to 50% flowering	Number of seeds / panicle	Plant spread (cm)	Number of days to 50% flowering	Number of seeds/ panicle
N_1S_1	57.9	50.6	66.8	57.6	50.6	66.4
N_1S_2	62.4	54.4	62.2	61.8	52.8	61.8
N_1S_3	70.1	55.8	59.8	69.0	55.2	63.8
N_2S_1	54.3	51.4	64.6	54.3	51.6	65.0
N_2S_2	61.3	53.6	63.2	61.3	53.4	64.8
N_2S_3	65.7	53.8	67.8	64.3	54.0	66.6
N_3S_1	56.5	49.8	65.4	56.7	50.4	65.4
N_3S_2	60.9	51.6	68.4	60.3	51.6	65.4
N_3S_3	62.3	50.0	73.2	61.8	50.0	73.2
N_4S_1	62.4	51.4	68.0	62.4	50.8	67.2
N_4S_2	60.8	50.2	68.0	60.6	50.2	68.0
N_4S_3	58.4	49.4	72.0	57.8	49.8	70.4
LSD (P=0.05)	1.02	1.43	2.63	1.59	1.48	5.14

REFERENCES

Ravi N and Mohanan N. 2002. *Common Tropical and Sub Tropical Sedges and Grasses.* Oxford and IBH Publishing Co. Pvt. Ltd. 219 p.

Duary B, Mukhopadhyay SK and Das TK. 2000. Autecological studies of pimpernel (*Anagallis arvensis* L). *Annals of Agricultural Research* **21**: 242-247.

Moody K. 1980. *Crop Loss Assessment in Rice.* International Rice Research Institute, Los Banos, Laguna, Philippines, 193 p.

Rao VS. 2000. *Principles of Weed Science.* Oxford and IBH publishing Co., New Delhi, 555 p.

Zimdahl RL. 1980. Weed-crop competition – Review, pp.41-46 In: *Proceedings of Conference.* International Plant Protection Center, Orgegon State Univ., Corvallis.

Short communication

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Weed management in chickpea under irrigated conditions

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Key words: Chickpea, Clodinafop-propargyl, Pinoxaden, Pendimethalin, Post-emergence, Weed control

In Haryana, the area under chickpea crop has reduced to 0.12 million hectare in 2008-09 from 1.06 million hectare in 1966-67 (Anonymous 2008). Among various barriers such as brackish irrigation water, hungry and discarded soils, lack of promising cultivars, improper fertilization, pest and diseases, poor weed management is one of the most important yield limiting factors in chickpea. Weed infestation in chickpea offer serious competition and cause yield reduction to the extent of 75% (Chaudhary *et al*. 2005). The initial 60 days period considered to be the critical for weed-crop competition in chickpea (Singh and Singh 1992). But with the increase in labour cost and scarcity of labour, manual weed control has become a difficult task in chickpea. Suitable herbicide for effective control of mixed weed flora is required for better adoption in this crop by farmers. Hence, present investigation was carried out to study the efficacy of different herbicides on mixed weed flora and their effect on growth and yield of chickpea at Kaul (Kaithal) in Haryana.

The soil of the experimental field was clay-loam, low in organic carbon and available nitrogen, medium in phosphorus, high in potash and alkaline in reaction. Chickpea variety '*C-235'* was sown on November 18, 2010. The experiment was laid out in randomized block design with twelve weed control treatments, *viz*. clodinafop 60 g/ha at 45 DAS, pinoxaden 50 g/ha at 45 DAS, clodinafop 60 g/ha at 45 DAS + one hoeing at 70 DAS, pinoxaden 50 g/ha at 45 DAS + one hoeing at 70 DAS, pendimethalin 1000 g/ha as pre-3m34g3nc3 (PE), trifluralin 1000 g/ha as pre-plant incorporation (PPI), pendimethalin 1000 g/ha as PE *fb* clodinafop 60 g/ha at 45 DAS, trifluralin 1000 g/ha as PPI *fb* clodinafop 60 g/ha at 45 DAS, pendimethalin 1000 g/ha as PRE *fb* pinoxaden 50 g/ha at 45 DAS, two hand weeding, weedy check and weed free. The experimnet was replicated thrice. Recommended package of practices except weed control treatments were followed for raising the crop. The density and dry weight of weds was recorded at 50 DAS and chickpea yield at harvest. WCE was calculated on the basis of dry weight of weeds.

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Chenopodium album, *Medicago denticulata* and *Phalaris minor* were the most dominant weeds in experimental area and constituted 44.6, 29.9 and 15.3% of the total weed population, respectively. Two hand weeding treatment recorded the lowest population of all the weed species. Among herbicides, pendimethalin and trifluralin treatments controlled *C. album, M. denticulate* and other species effectively and recorded significantly lower population than all other treatments. Pendimethalin *fb* pinoxaden recorded significant reduction in population of *C. album, M. denticulata, P. minor* and other species and it was statistically similar to pendimethalin *fb* clodinafop and pendimethalin alone. However, pendimethalin alone was significantly poor in reducing weed population of other species (Table 1). Chaudhary *et al.* (2005) also reported the control of monocot and dicot weeds by pendimethalin. *P. minor* was higher in trifluralin at 1000 g/ha as PPI among the herbicide treatments. Weed control efficiency was highest in weed free treatment. Two hand weeding was the next best treatment with WCE (84.3%) which was statistically alike to pendimethalin *fb* pinoxaden and pendimethalin *fb* clodinafop. Pinoxaden or clodinafop treatments effectively controlled *P. minor*. Yadav *et al.* (2009) reported excellent efficacy of pinoxaden 50 g/ha against grassy weeds in wheat crop especially resistant population of *P. minor.*

Weed free treatment recorded the highest number of branches and pods per plant, 100-seed weight and also seed yield (0.98 t/ha) which were statistically at par with two hand weeding, pendimethalin *fb* pinoxaden and pendimethalin *fb* clodinafop. No significant difference in weed control treatments was recorded in respect of number of grains/pod (Table 2). Weedy check produced 68% lower seed yield as compared to weed free which was attributed to the 42, 7, 16 and 43 per cent less number of pods/plant, grains/pod, 100-seed weight and branches over weed free, respectively. The higher values of these attributes are the indirect effect of better plant growth in weed free treatment. Sharma and Singh (2005) reported highest chickpea yield under weed free treatment followed by

Table 1. Effect of weed control treatments on weed growth and performance of chickpea

Treatment	Dose (g/ha)	Application time (DAS)	Density (no. / m^2)				WCE (%)	Pods/ plant	100 grain wt. (g)	No. of grains/ pod	Grain yield (t/ha)
			C. album	*Medicago denticulate*	*P.minor*	Other spp.					
Clodinafop	60	45	8.02 (63.40)	6.49 (43.33)	3.14 (8.86)	3.41 (10.63)	14.2	33.16	11.48	1.34	0.73
Pinoxaden	50	45	7.88 (61.26)	6.60 (42.64)	3.11 (8.73)	3.40 (10.56)	14.6	35.43	11.63	1.35	0.77
Clodinafop + one hoeing at 70 DAS	60	45	7.93 (61.73)	6.67 (43.54)	3.09 (8.57)	3.39 (10.52)	82.5	37.33	11.73	1.36	0.88
Pinoxaden + one hoeing at 70 DAS	50	45	7.89 (61.06)	6.50 (41.26)	3.08 (8.50)	3.36 (10.34)	82.9	37.46	12.01	1.38	0.88
Pendimethalin	1000	PRE	4.75 (21.60)	4.43 (18.70)	2.50 (5.27)	2.74 (6.53)	77.4	44.97	12.63	1.39	0.92
Trifluralin	1000	PPI	5.25 (26.40)	4.96 (23.66)	3.16 (9.08)	2.83 (7.02)	75.9	43.43	12.03	1.38	0.86
Pendimethalin *fb* clodinafop	1000 and 60	PRE and at 45 DAS	4.74 (21.50)	4.36 (18.07)	2.45 (5.03)	2.60 (5.80)	81.3	45.93	13.16	1.40	0.94
Trifluralin *fb* clodinafop	1000 and 60	PPI and at 45 DAS	5.04 (24.63)	4.56 (19.83)	3.03 (8.17)	2.77 (6.70)	77.0	41.64	11.89	1.38	0.90
Pendimethalin *fb* pinoxaden	1000 and 50	PRE and at 45 DAS	4.36 (18.06)	4.22 (16.89)	2.44 (4.96)	2.56 (5.56)	82.3	46.01	13.19	1.30	0.94
Two hand weeding		45 and 70 DAS	1 (0)	1 (0)	1 (0)	1 (0)	84.3	47.33	13.22	1.39	0.96
Weedy check			8.5 (72.06)	7.38 (53.50)	4.99 (24.0)	3.80 (13.50)	0.0	27.84	11.14	1.31	0.58
Weed free			1 (0)	1 (0)	1(0)		100	48.43	13.35	1.41	0.98
LSD(P=0.05)			0.43	0.26	0.14	0.12	3.84	3.50	0.48	NS	00.45

Figures in the parentheses indicate $(\sqrt{x+1})$ transformed data DAS = Days after sowing

two hand weeding at 25 and 45 DAS. The lower grain yield of chickpea was recorded in clodinafop or pinoxaden treated plots as these treatments failed to control broad leaf weeds which were dominant in the experimental field.

SUMMARY

Pendimethalin 1000 g/ha as pre-emergence effectively controlled C. *album, M. denticulata* and *Phalaris minor.* Pinoxaden 50 g/ha and clodinafop 60 g/ha as post-emergence were effective in controlling only *P. minor*. Pinoxaden and trifluralin were slightly phytotoxic to chickpea plants, which recovered later on. The highest grain yield was obtained in weed free treatment which was at par with two hand weeding, pre-emergence use of pendimethalin at 1000 g/ha *fb* pinoxaden at 50 g/ha applied at 45 DAS and pendimethalin at 1000 g/ha *fb* clodinafop at 60 g/ha applied at 45 DAS. Presence of weeds throughout crop season reduced the seed yield up to 68%.

REFERENCES

Anonymous. 2008. *Area and Production of Major Crops in India*. Ministry of Agriculture. Govt. of India.

Chaudhary BM, Patel JJ and Delvadia DR. 2005. Effect of weed management practices and seed rates on weeds and yield of chickpea. *Indian Journal of Weed Science* **37**: 271-272.

Sharma SK and Singh V. 2005. Weed control in chickpea (*Cicer arietinum* L.) under dryland conditions. *Haryana Journal of Agronomy* **21**(1): 24-25.

Singh G. and Singh D. 1992. Weed-crop competition studies in chickpea (*Cicer arietinum*). *Indian Journal of Weed Science* **24**(1&2): 1-5.

Yadav DB, Punia SS, Yadav A, Singh S and Lal R. 2009. Pinoxaden: An alternate herbicide against little seed canary grass (*Phalaris minor*) in wheat (*Triticum aestivum*). *Indian Journal of Agronomy* **54**(4): 433-437.

Short communication

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Weed management in groundnut with imazethapyr + surfactant

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Groundnut (*Arachis hypogaea* L.) is most important oilseed crop of India grown during rainy season. The slow initial growth of groundnut and favourable weather conditions during rainy season allow the weeds to grow faster. Season long weed competition reduces the yield as high as 24 to 70% (Wani *et al*. 2010). The first three-four weeks of crop growth period are critical for weed control in groundnut (Mulik *et al*. 2010). During rainy season, effective and economical weed control is not possible through manual and mechanical weeding due to unfavourable soil condition and also the unavailability of costly laborers. Herbicides have been accepted as cost-effective tool to manage weeds menace in groundnut. There are number of pre-emergence herbicides such as oxyfluorfen, fluchloralin, pendimethalin *etc*. which are being used for weed control in groundnut. However, they often fail to control weeds emerging during early vegetative phase of the crop. Imazethapyr applied as pre-plant incorporated, pre-emergence, early post-emergence or late post-emergence controlled many weeds in groundnut (Wilcut *et al*. 1995). Imazethapyr is the first herbicide registered in peanut to provide both post-emergence and residual control of many problem weeds (Grichar and Sestak 2000). Therefore, the present study was undertaken to evaluate the bio-efficacy of imazethapyr 10 per cent SL, as early post-emergence against important weeds of groundnut under agro-climatic condition of Varanasi in Eastern Uttar Pradesh.

A field experiment was conducted during *Kharif* season 2009 at Institute of Agricultural Sciences, BHU, Varanasi (23.2^0 N latitude, 83.03^{0}E longitude and at an altitude of 113 msl). The soil of experimental site was sandy clay loam in texture with saline in reaction (pH-7.2). It was low in organic C (0.32%) and available nitrogen (168.9 kg/ha), medium in available phosphorus (26.6 kg/ha) and potassium (242.5 kg/ha). The total rainfall received during 2008 was 742.8 mm of which 353.2, 333.2 and 56.2 mm, respectively was received during July, August and September. The field was kept under rice-wheat rotation for the last eight years. Treatments consisted of imazethapyr 10% SL, 75 g/ha + 0.2% surfactant, imazethapyr 10% SL, 100 g/ha + 0.2% surfactant, imazethapyr 10% SL, 125 g/ha + 0.2% surfactant, imazethapyr 10% SL, 200 g/ha + 0.2% surfactant, imazethapyr 10% SL, 100 g/ha + 0.2% surfactant (market sample), oxyfluorfen 23.5% EC 250 g/ha, weed free check and untreated control in completely randomized block design with three replications. The groundnut variety '*Type-28*' was sown manually at 45 x 15 cm row spacing using 80 kg seed/ha on 2nd August 2008 in 4.6 x 3.6 m^2 plot. Crop was raised with recommended package of practices for the region. Herbicides were applied as per treatments with hand sprayer fitted with flatfan nozzle and the spray volume was 400 litters/ha after two days of sowing. Density, dry weight and weed control efficiency of weeds were observed at 30 and 45 days after sowing of crop. Data on weed density was recorded from an area enclosed in the quadrate of 0.25/m^2 randomly selected at four places in each plot. Weed species were separately counted from each sample and their density was recorded as average number/m^2. Weed data were subjected to square root transformation ($\sqrt{x + 0.5}$) before statistical analysis.

The major weeds in experimental crop were *Echinochloa colona* (15.4%), *Cyperus rotundus* (16.1%), and *Dactyloctenium aegyptium* (20.9%) among narrow-leaf weeds and *Trianthema portulacastrum* (47.5%) was the major broad-leaf weed.

Application of imazethapyr 200 g/ha + surfactant recorded minimum density of all the dominant weed species and it was at par to its lower rates of 100 and 125 g/ha, irrespective of stages of observation (Table 1). Test sample of imazethapyr 100 g/ha + surfactant recorded less density of weeds than market sample (Pursuit) at same rate, but both remained at par with each other. Pre-emergence application of oxyfluorfen 250 g/ha effectively controlled the *Dactyloctenium aegyptium* and *Trianthema portulacastrum* whereas, it was least effective against

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Echinochloa colona and *Cyperus rotundus* and had significantly higher density of these weed species when compared with imazethapyr 100-200 g/ha + surfactant. The results were corroborated with the findings of Grichar and Sestak (2000).

Test sample of imazethapyr 100 g/ha + surfactant did not differ significantly from its higher rates (125 and 200 g/ha) in respect of dry matter accumulation by weeds, irrespective of stage of observation. Imazethapyrat 100 g/ha + surfactant was comparable to market sample of imazethapyr (Pursuit) at 100 g/ha + surfactant and was significantly superior over pre-emergence application of oxyfluorfen 250 g/ha. However, all the herbicides were significantly superior to untreated control. The results were in line with those of Wilcut *et al.* (1995) and Wani *et al.* (2010).

Weed control efficiency varied from 39.8 to 66.6% at 30 DAS and 29.2 to 65.9% at 45 DAS under different weed control treatments. Among the herbicidal treatments, highest weed control efficiency (66.6 and 65.9%) was also recorded under imazethapyr 200 g/ha + surfactant followed by imazethapyr 125 g/ha + surfactant, imazethapyr100 g/ha + surfactant and imazethapyr 75 g/ha + surfactant (market sample), respectively. Lower weed control efficiency (39.8 and 29.2) was recorded under pre-emergence application of oxyfluorfen 250 g/ha (Table 1). Weed free check recorded the highest weed control efficiency (100%) over other weed control treatments.

On the basis of visual observation at 5 days after spraying of herbicide, the phytotoxicity of higher rate was compared with untreated control and also lowers rates of imazethapyr. No-phytotoxicity symptoms appeared on crop even at higher rate (200 g/ha) of the herbicide.

The seed and haulm of yield of groundnut was significantly affected by different weed control treatments (Table 1). Among the herbicidal treatments, imazethapyr 200 g/ha + surfactant was recorded significantly the highest seed and haulm yield over imazethapyr 100 g/ha + surfactant (market sample), imazethapyr 75 g/ha + surfactant and oxyflurfen 250 g/ha and were at par with imazethapyr 100 and 125 g/ha + surfactant. However, all the rates of herbicides were significant superior to untreated control. Higher yield under imazethapyr 200 g/ha + surfactant was mainly due to effective control of narrow and broadleaf weeds in groundnut, leading to synergistic effect on growth and yield attributes. The results were in close conformity with the finding of Dowler (1992), Wilcut *et al.* (1993), Wilcut *et al.* (1995), Mulik *et al.* 2010 and Wani *et al.* (2010).

The regression equation predicted linear reduction in the seed yield with a unit increase in the dry weight of weeds (Fig. 1). The extent of reduction could be 33.4 kg/ha for weed dry weight. The evaluation of weed control efficiency of the different treatments and the regression of yield on it revealed that 1% increase in the weed control efficiency increased the grain yield by 13.6 kg/ha (Fig. 2).

Table 1. Effect of imazethapyr + surfactant on weed growth at 45 DAS and yield of groundnut

Treatment	Dose (g/ha)	Weed density (no./m^2) *Echinochloa colona*	*Cyperus rotundus*	*Trianthima portulacastrum*	*Dactylocteniu maegyptium*	Total weed dry weight (g/m^2)	Weed control efficiency (%)	Seed yield (t/ha)	Haulm yield (t/ha)	Harvest index
Imazethapyr + 0.2% surfactant	75	2.37 (6.0)	3.53 (12.0)	9.11 (82.7)	3.81 (14.3)	5.18 (26.3)	35.5			
Imazethapyr + 0.2% surfactant	100	2.25 (6.7)	3.43 (11.3)	8.43 (72.7)	3.43 (11.3)	4.85 (23.0)	43.6	2.04	5.47	0.27
Imazethapyr + 0.2% surfactant	125	1.94 (3.3)	1.64 (2.7)	8.21 (67.0)	2.95 (8.3)	4.11 (16.4)	59.8	2.10	5.97	0.26
Imazethapyr + 0.2% surfactant	200	1.27 (1.3)	1.35 (1.7)	6.91 (47.3)	2.58 (6.3)	3.80 (13.9)	65.9	2.23	6.22	0.26
Imazethapyr + 0.2% surfactant (market sample)	100	2.81 (7.5)	3.6 (12.2)	8.89 (78.6)	3.60 (12.5)	5.22 (26.8)	34.3	1.99	5.09	0.28
Oxyflurfen 23.5% EC	250	5.80 (32.4)	3.92 (15.0)	5.20 (26.7)	5.40 (28.6)	5.43 (28.9)	29.2	1.26	4.57	0.22
Weed free check (two hand weeding)	20 & 40 DAS	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	100.0	2.47	6.67	0.27
Untreated control		5.89 (34.3)	6.04 (36.0)	10.3 (106)	6.84 (46.7)	6.43 (40.8)	-	1.20	3.55	0.25
LSD (P=0.05)		1.20	0.78	0.72	0.69	0.72	-	0.24	0.63	-

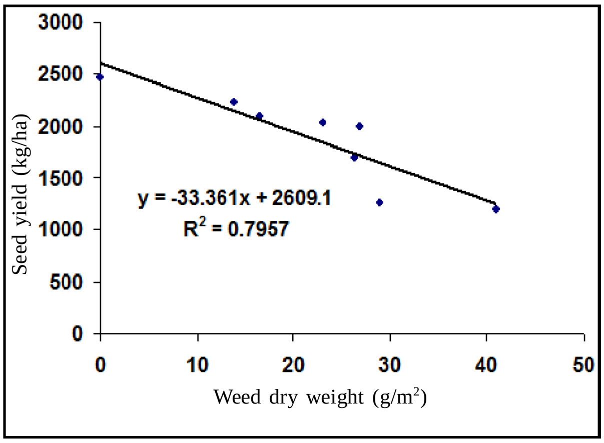

Fig. 1. Reationship between weed dry weight and seed yield of groundnut

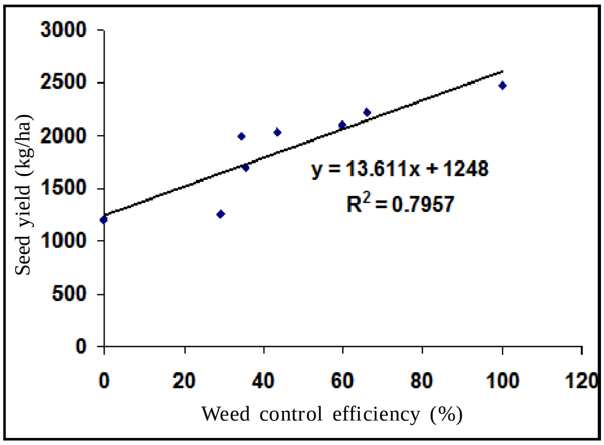

Fig. 2. Reationship between weed control efficiency and seed yield of groundnut

SUMMARY

An experiment was conducted during *Kharif* season of 2009 at BHU, Varanasi to evaluate the bio-efficacy of imazethapyr 10% SL + surfactant against important weeds of groundnut. Application of imazethapyr 200 g/ha + surfactant being at par with its lower rates of 100 and 125 g/ha, reduced the density of dominant weeds. Pre-emergence application of oxyfluorfen 250 g/ha effectively controlled the *Dactyloctenium aegyptium* and *Trianthema portulacastrum* whereas, it was least effective against *Echinochloa colona* and *Cyperus rotundus*. Imazethapyr 200 g/ha + surfactant recorded significantly the highest seed and haulm yield and weed control efficiency over imazethapyr 100 g/ha + surfactant (market sample), imazethapyr 75 g/ha + surfactant and oxyfluorfen 250 g/ha. There was no-phytotoxicity symptoms on crop even at higher rate (200 g/ha) of the herbicide.

REFERENCES

Dowler CD. 1992. Weed survey of Southern states. *Proceedings of South Weed Science Society* **45**: 393-397.

Grichar WJ and Sestak DC. 2000. Effect of adjuvant on control of nutsedge (*Cyperus esculentus* and *C. rotundus*) by imazapic and imazethapyr. *Crop Protection* **19**: 461-465.

Mulik BB, Malunjkar BD, Kankal VY and Patil SC. 2010. Chemical weed control in *Kharif* groundnut (*Arachis hypogaea* L.), pp 86. In: *National Symposium on Integrated Weed Management in the Climate Change*, NASC, New Delhi, 21-22 August, 2010.

Wani AG, Bodake PS, PatilV S, Ugale NS and. Patil HM. 2010. Boi-efficacy of imazethapyr formulations against weeds in *Kharif* groundnut (*Arachis hypogaea* L.), p. 101. In: *National Symposium on Integrated Weed Management in the Climate Change*, NASC, New Delhi, 21-22 August, 2010.

Wilcut JW, York AC and Wehtje GR. 1993. The control and interaction of weeds in peanut (*Arachis hypogaea*). *Review of Weed Science* **6**: 177-206.

Wilcut JW, York AC, Grichar WJ and Wehtje GR. 1995. The biology and management of weeds in peanut (*Arachis hypogaea*), pp. 207-244. In: *Advances in Peanut Science*. (Eds. Pattee HE, Stalker HT. Inc. and Stillwater). American Peanut Research Education Society.

Short communication

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Residual effects of soybean herbicides on the succeeding winter crops

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Pendimethalin is a dinitroaniline herbicide used for selective control of annual grasses and few small seeded broad-leaved weeds in several crops. It is absorbed by the roots and leaves, and inhibits cell division and cell elongation (BCPC and RSC,1994). Quizalofop-p-ethyl is a widely used selective, post-emergence aryloxyphenoxypropionate herbicide and is used to control annual and perennial grass weeds in soybean and other broad-leaved crops. It inhibits the acetyl CoA carboxylase enzyme, necessary for lipid synthesis in the plants. The imidazolinone herbicides (imazethapyr and imazamox) inhibit acetolactate synthase (ALS), a key enzyme in the biosynthesis of branched-chain amino acids valine, leucine, and isoleucine. Once in the phloem and translocated to the site of action, the imidazolinones inhibit ALS, causing death of meristematic cells resulting in plant death (Masson and Webster 2001). They are applied either pre- or post-emergence as selective herbicides for broad-spectrum control of broad-leaf weeds and grasses in soybean and several other leguminous crops (Barkani *et al.* 2005). Wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), spinach (*Spinacia oleracea*), pea (*Pisum sativum*), raya (*Brassica juncea*), canola (*Brassica napus*) and sugarbeet (*Beta vulgaris*) are the important succeeding crops, grown after soybean in Punjab and neighbouring states of Haryana and Rajasthan. The crops have differential sensitivity to different herbicides. Sugar beet showed the highest sensitivity to imazamox followed by spinach, oilseed rape, fennel, cauliûower and lettuce that were damaged by imazamox while wheat, sunûower, grain sorghum and maize were far less sensitive to imazamox residues (Pannacci *et al.* 2006). Hence, studies on the residual effects of herbicide on the succeeding crops are important, before it is finally recommended for field applications to the farmers.

Chemical methods and plant bioassays are most frequently used for the assessment of herbicide residues in soil. Plant bioassays are simple and inexpensive and measure a phytotoxic portion of soil residual herbicide, which typically varies with soil type and plant species. There are fewer published details on use of field bioassay for measuring the residual effects of pendimethalin, quizalofop, imazethapyr and imazamox on wheat, barley, spinach, pea, raya, canola and sugarbeet. In the present study, the residual effects of pendimethalin, quizalofop, premix of imazethapyr + imazamox, applied to soybean, on the succeeding winter crops were determined through field bioassay during winter 2013-14 at Ludhiana, India. The soil was loamy sand, low in organic carbon and available nitrogen and medium in available phosphorus and available potassium. The soil pH (7.6) and electrical conductivity (0.2/dsm) values were within the normal range. Soybean variety '*SL 744*' was seeded on June 8, 2013. The crop was supplied with fifteen weed control treatments *viz.* pendimethalin at 450 g/ha as pre-emergence alone and followed by one hoeing at 40 days after sowing, premix of imazethapyr + imazamox at 60 and 70 g/ha each at 3 and 4 weeks after sowing (WAS), quizalofop at 37.5 and 50.0 g/ha at 3 WAS, pendimethalin at 450 g/ha *fb* premix of imazethapyr + imazamox at 60 and 70 g/ha at 4 WAS/ quizalofop at 37.5 and 50.0 g/ha at 4 WAS, pre-mix of imazethapyr + imazamox at 60 and 70 g/ha at 3 WAS *fb* quizalofop at 37.5 g/ha at 6 WAS and unsprayed check, laid out in a randomized complete block design with four replications.

After the harvest of soybean in mid-November 2013, the field was prepared by giving light cultivation followed by planking, without disturbing the original layout. Two rows of each of the succeeding winter season crops *viz.* wheat (cv. '*HD 2967*'), barley (cv. '*PL 807*', spinach (cv. '*PB Green*'), pea (cv. '*PB 89*'), raya (cv. '*RLM 619*'), canola (gobh-isarson) (cv. '*GSC 6*') and sugarbeet (cv. '*Shubra*') were sown in each plot, in rows spaced at 20 cm on 25 November 2013.These crops were raised as per package of practices recommended by PAU Ludhiana. The data on seedling emergence, plant height and dry matter

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Table 1. Residual effects of herbicides on plant height (cm) of succeeding crops at 40 days after sowing

Treatment	Wheat	Barley	Spinach	Pea	Raya	Canola	Sugarbeet
Pendimethalin 450 g/ha	11.3	13.7	5.9	10.9	12.8	9.1	5.2
Pendimethalin 450 g/ha *fb* hoeing at 40 DAS	10.1	11.4	4.9	12.4	10.9	7.8	4.3
Imazethapyr + imazamox 60 g/ha at 3 WAS	11.7	13.9	5.0	11.1	12.7	7.3	4.6
Imazethapyr + imazamox 60 g/ha at 4 WAS	13.0	12.5	5.9	11.7	13.5	8.8	5.1
Imazethapyr + imazamox 70 g/ha at 3 WAS	12.1	13.0	5.3	12.6	11.5	7.5	4.5
Imazethapyr + imazamox 70 g/ha at 4 WAS	12.5	14.4	5.4	13.6	12.7	9.0	5.3
Pendimethalin 450 g/ha *fb*imazethapyr + imazamox 60 g/ha at 4 WAS	12.0	13.0	4.9	10.9	12.7	7.3	4.9
Pendimethalin 450 g/ha fbimazethapyr + imazamox 70 g/ha at 4 WAS	12.5	12.7	5.4	13.1	11.7	7.1	4.2
Quizalofop 37.5 g/ha at 3 WAS	12.3	12.8	4.9	13.0	12.7	7.2	4.6
Quizalofop 50.0 g/ha at 3 WAS	12.1	11.7	5.6	11.3	13.1	8.8	5.3
Pendimethalin 450 g/ha *fb*quizalofop 37.5 g/ha at 4 WAS	11.8	13.3	5.7	10.0	12.1	7.3	4.5
Pendimethalin 450 g/ha *fb*quizalofop 50.0 g/ha at 4 WAS	12.1	14.6	5.3	11.5	13.5	7.9	5.1
Imazethapyr + imazamox 60 g/ha at 3 WAS *fb*quizalofop 37.5 g/ha at 6 WAS	11.6	14.3	5.5	13.1	12.2	9.3	4.5
Imazethapyr + imazamox 70 g/ha at 3 WAS *fb*quizalofop 37.5 g/ha at 6 WAS	12.6	13.4	4.6	13.5	13.2	7.5	5.0
Unsprayed check	11.5	13.3	5.1	12.1	11.9	7.3	5.1
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

Table 2. Residual effects of herbicides on dry matter accumulation (g/m²) of succeeding crops at 40 days after sowing

Treatment	Wheat	Barley	Spinach	Pea	Raya	Canola	Sugarbeet
Pendimethalin 450 g/ha	48.5	60.6	15.8	10.9	55.2	22.0	4.3
Pendimethalin 450 g/ha *fb* hoeing at 40 DAS	45.1	50.6	13.0	10.7	49.8	22.8	4.0
Imazethapyr + imazamox 60 g/ha at 3 WAS	52.3	54.8	14.9	11.3	53.8	24.8	3.9
Imazethapyr + imazamox 60 g/ha at 4 WAS	49.1	50.6	13.5	9.9	52.4	22.8	4.5
Imazethapyr + imazamox 70 g/ha at 3 WAS	54.9	55.8	13.8	12.2	53.7	26.0	3.7
Imazethapyr + imazamox 70 g/ha at 4 WAS	51.1	56.3	15.9	10.4	51.8	25.9	3.9
Pendimethalin 450 g/ha *fb* imazethapyr + imazamox 60 g/ha at 4 WAS	49.1	52.1	12.9	10.6	54.2	24.0	3.9
Pendimethalin 450 g/ha *fb* imazethapyr + imazamox 70 g/ha at 4 WAS	47.7	59.1	13.0	9.6	53.0	26.2	3.6
Quizalofop 37.5 g/ha at 3 WAS	51.7	53.3	13.4	12.2	53.0	26.0	3.6
Quizalofop 50.0 g/ha at 3 WAS	44.5	51.4	13.0	11.4	52.7	23.2	4.7
Pendimethalin 450 g/ha *fb*quizalofop 37.5 g/ha at 4 WAS	50.4	55.4	13.2	11.3	49.5	24.6	4.2
Pendimethalin 450 g/ha *fb* quizalofop 50.0 g/ha at 4 WAS	57.6	58.0	13.2	11.8	53.8	23.9	4.5
Imazethapyr + imazamox 60 g/ha at 3 WAS *fb* quizalofop 37.5 g/ha at 6 WAS	55.7	55.7	15.0	10.0	51.1	24.2	4.3
Imazethapyr + imazamox 70 g/ha at 3 WAS *fb* quizalofop 37.5 g/ha at 6 WAS	51.0	57.0	15.5	10.9	53.8	24.3	5.0
Unsprayed check	51.0	55.7	13.4	12.5	54.1	25.0	5.0
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

accumulation by succeeding crops were recorded at 40 days after sowing. All the data were analyzed using the SAS Proc GLM (SAS 9.1). Differences between the treatments were determined using Fisher's protected LSD (P=0.05).

The results indicated that the herbicides applied to soybean did not show any significant effect on seedling emergence (data not shown), plant height and dry matter accumulation of all the succeeding crops,*viz.* wheat, barley, spinach, pea, raya, canola and sugarbeet (Table 1 and 2), indicating the safety of all the three herbicides, used alone or in sequence, for all the succeeding crops grown in rotation with soybean. The residual effects of herbicides depend upon soil texture, soil reaction, organic matter content and climatic conditions of a place. A long time gap between application of herbicides and crop harvest, microbial degradation, and precipitation cause the degradation and leaching down of the herbicide (Idapuganti *et al.* 2005). Pendimethalin at 1.0 and 1.5 kg/ha remained biologically active up to 25 to 26 days in sandy loam soil; 75% pendimethalin was lost in 45 days (Kewat 1998). At pH 7, the half-life for imazamox was 10 days and for imazethapyr was 112 days (Aichele and Penner 2005). In moist sand, 52% of imazethapyr was degraded within 48 hour of exposure to UV light (Curran *et al.* 1992). In the present study, there was long time gap of 124 to 168 days between the applications of different herbicides to soybean to sowing of succeeding crop,which seemed to be sufficient for degradation of the herbicides.The results indicated that all the above herbicides at the doses tested, used for weed control in soybean, are safe for raising of wheat, barley, spinach, pea, raya, canola and sugarbeet, in rotation with soybean.

SUMMARY

The residual effects of pendimethalin, quizalofop, imazethapyr and imazamox, applied to soybean crop, on the succeeding winter season crops, *viz*. wheat, barley, spinach, pea, raya, canola and sugarbeet were determined through field bioassay at Ludhiana in 2013-14. Soybean was supplied with fifteen weed control treatments, *viz*. pendimethalin at 450 g/ha as pre-emergence alone and followed by (*fb*) hoeing, imazethapyr + imazamox at 60 and 70 g/ha each at 3 and 4 weeks after sowing (WAS), quizalofop 37.5 and 50.0 g/ha at 3 WAS, pendimethalin 450 g/ha *fb* imazethapyr + imazamox 60 and 70 g/ha at 4 WAS/quizalofop at 37.5 and 50.0 g/ha at 4 WAS, imazethapyr + imazamox 60 and 70 g/ha at 3 WAS *fb* quizalofop 37.5 g/ha at 6 WAS and unsprayed check. The emergence, plant height and dry matter accumulation of all the succeeding crops were similar among herbicidal and unsprayed plots indicating that all the herbicides are safe for raising of these winter crops in rotation with soybean.

REFERENCES

Aichele TM and Penner D. 2005. Adsorption, desorption and degradation of imidazolinones in soil. *Weed Technology* **19**: 154-159.

Barkani H,Catastini C,Emmelin C, Sarakha M, Azzouzi ME and Chovelon JM. 2005. Study of the phototransformation of imazaquin in aqueous solution: a kinetic approach. *Journal of Photochemistry and Photobiology A: Chemistry* **170**: 27-35.

British Crop Protection Council and Royal Society of Chemistry. 1994. *The Pesticide Manual*, 10th ed.: BCPC and RSC, London, UK.

Curran WS, Loux MM, Liebl RA and Simmons FW. 1992. Photolysis of imidazolinone herbicides in aqueous solution and on soil. *Weed Science* **40**: 143-148.

Idapuganti RG, Rana DS and Sharma R. 2005. Influence of integrated weed management on weed control and productivity of soybean (*Glycine max*). *Indian Journal of Weed Science* **37**: 126-128.

Kewat ML. 1998. *Direct and residual effect of herbicides on soybean-wheat sequence*. Ph.D. thesis. Indian Agricultural Research Institute, New Delhi, India.

Masson JA and Webster EP. 2001. Use of imazethapyr in water-seeded imidazolinone-tolerant rice (*Oryzasativa*). *Weed Technology* **15**: 103-106.

Pannacci E, Onofri A and Covarelli G. 2006. Biological activity, availability and duration of phytotoxicity for imazamox in four different soils of central Italy. *Weed Research* **46**: 243-250.