Indian Journal of Weed Science

Print ISSN 0253-8040
Online ISSN 0974-8164

Volume – 52 | Number – 3
July – September, 2020

Available Online @ www.indianjournals.com

Indian Society of Weed Science

ICAR-Directorate of Weed Research
Jabalpur - 482004, India
Website: www.isws.org.in

INDIAN SOCIETY OF WEED SCIENCE

(Founded in 1968)

Regd. S. No. SOR/BLU/DR/518/08-09

IJWS REGD. NO. MAG (5) PRB 249/82-83

Indian Journal of
Weed Science

Volume 52 | Number 3 | July – September, 2020

Weed watch

Review article

Research articles

Research notes

The papers published in this journal are selectively abstracted and indexed in Google Scholar, CABI, Crossref, Efita.org, OAJI.net, Research Bible, Citefactor, CNKI Scholar, EBSCO Discovery, Summon Proquest, Indian Citation Index (ICI), Indian Science Abstracts, J-Gate and other major abstracting services of the world. Each paper bears a DOI number to facilitate online identity and access.

After consulting instructions on link http://isws.org.in/IJWSn/Journal.aspx, authors should submit their articles online only. Articles are not accepted through email or post. Please log directly on to http://isws.org.in/login_IJWS.aspx and upload your manuscript following the on-screen instructions.

Membership rates of Indian Society Weed Science (for the year 2020)		
	INDIA	FOREIGN
Individual (Annual)	₹ 500.00	US$ 50.00
Individual (Life)	₹ 6,000.00	US$ 300.00
Institution Libraries	₹ 10,000.00	US$ 300.00
Sustaining industries (Annual)	₹ 20,000.00	-
Sustaining industries (Life)	₹ 50,000.00	-
Please submit form online: http://isws.org.in/Member_r.aspx		

Indian Journal of Weed Science **52**(3): 200–203, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Parthenium weed spread in Andaman & Nicobar and Lakshadweep Islands of India: Lurking invasion needs attention for its eradication

B. Gangaiah*, T. Subramani, Sanjeev Kumar Singh[1], A.K.O. Ratheesh[2] and Sushilkumar[3]

Division of Natural Resource Management, ICAR-Central Island Agricultural Research Institute, Port Blair, Andaman and Nicobar Islands 744 105, India

[1]Krishi Vigyan Kendra, Nicobar, Port Blair, Andaman & Nicobar Islands 744 105, India

[2]ICAR-CIARI Regional Station, Minicoy, Lakshadweep 682 559, India

[3]ICAR-Directorate of Weed Research, Jabalpur, Madhya Pradesh 482 004, India

**Email: bandlagangaiah1167@gmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00038.6

Type of article: Weed watch

Received : 18 April 2019
Revised : 28 July 2020
Accepted : 5 August 2020

Key words

Senna tora
Dermatitis
Islands
Parthenium
Zygogramma bicolorata

ABSTRACT

Parthenium (*Parthenium hysterophorus* L.) has traversed the oceans to reach Andaman & Nicobar and Lakshadweep Islands of India in early 21st century, nearly half a century after its first report in Maharashtra state in 1955. Its entry might be on account of contaminated movement of food grains and other materials with Parthenium seeds from mainland through ships and airplanes. The weed has established in wastelands and community lands in some of the islands, hence there is lurking threat of its further invasion in other islands and into croplands. Public were less aware of its harmful effects due its new occurrence in the region. Competitive plant *Senna tora* was noticed in the islands during survey, and was recommended for Parthenium management on the road side. Physical removal was done involving people participation and was recommended for its management due to ban on using of chemicals. Bioagent *Zygogramma bicolorata* was not found in Andaman & Nicobar Islands in spite of its introduction in 2005 and 2006 for its biological control.

Parthenium hysterophorus (L.) is an annual herb belonging to the sunflower family of Asteraceae (Compositae). The weed proliferation is so rapid that it has gained the status of world worst weeds by 1997 (Holm *et al.* 1997) and has entered into the group of 100 most invasive species of world (GISD 2018). In India, an attempt was made by Sushilkumar (2005) to trace the history of occurrence of Parthenium, which was found about one and half century old (Roxburghi 1914, Maiti 1983). Its presence in India before 1955 got further confirmation from a herbarium record in Forest Research Institute, Dehradun (Uttarakhand) collected by Dr. Brandis (1880), however it became wide spread only after its entry into the country as a contaminant of wheat grains supplied by USA to India as food aid under PL 480 scheme in 1950s. After 1880, this weed was first noticed in the country by Prof. Paranjape, a retired horticulturist, in Pune district, Maharashtra in 1955, and described by Rao (1956). Thereafter, it has rapidly disseminated to every nook and corner of the country infesting about 35 million hectares of land (Sushilkumar and Varshney 2009). First time, its presence in Andaman and Nicobar Islands (ANI) was reported in Diglipur area during floral survey in 2001 (Reddy 2013) and thereafter, its substantial presence was recorded in Port Blair by Sushilkumar (2005). Severe presence of Parthenium was reported in Minicoy Island of Lakshadweep in 2012 (Sushilkumar 2014). The two islands of Union Territories (UTs) of India are physically isolated from mainland by 280-400 (Lakshadweep Islands, of coral origin in Arabian sea) to over 1200 km (Andaman & Nicobar islands, of volcanic origin in Bay of Bengal). In view of harmful effects on men, animals and biodiversity, a study was done on its spread and method of management in Andaman & Nicobar and Lakshadweep Islands of India.

Occasional surveys were made in different parts of two islands (Lakshadweep and Andaman and Nicobar) during 2014 to 2017 for the presence of *Parthenium hysterophorus*, competitive plant *Senna tora* and other species, and bioagent *Zygogramma bicolorata*. Interactions were made with the inhabitants of different parts of the islands and government officials of agriculture, forests and public works departments to know whether people are aware about its harmful effects and control measures to contain it. Attempts were also made to make public aware about the weed by organising various activities like uprooting of Parthenium, display of posters, sowing of competitive plant to replace Parthenium *etc.* on the appeal of Directorate of Weed Research, Jabalpur during Parthenium Awareness Week.

Parthenium occurrence in the islands

Severe infestation of Parthenium was observed in Hut Bay Island, however low presence was also observed around the Port Blair airport boundary in South Andaman district. The weed was also recorded in Sawai tee-top village beach of tribal district of Nicobar in low intensity, which is separated by 10-degree channel from other 2 districts (**Figure 1a** and **1b**). Movement of organic manures and other food materials was suspected to be the causes of its appearance in Nicobar district. The unabated movement of Parthenium contaminated materials within the islands from mainland is aiding the threat of its spread to other islands that are free from it till now (Gangaiah *et al.* 2016, Gangaiah 2018).

In Minicoy island of Lakshadweep, severe infestation of Parthenium was recorded during survey, however this weed was not found in other islands of Lakshadweep. The mode of entry might be due to transport of Parthenium contaminated materials from the state of Kerala. Severe occurrence of Parthenium in Minicoy island of Lakshadweep was also reported in 2012 by Sushilkumar (2014), however, he categorised Andaman & Nicobar territory under low infestation category in context to overall spread. The presence of Parthenium weed in the Andaman and Nicobar Islands was first time noticed in 2001 (Reddy 2013). Its further spread might be due to transport of aid materials of food, manure, construction materials *etc*. aftermath of 26th December, 2004 massive earthquake followed by tsunami.

Impacts of parthenium on agriculture and health in the islands

No serious estimate on extent of Parthenium invasion into forests (occupying >85 of Andaman's geographical area), wastelands and community lands has been assessed yet. There are no forests in Lakshadweep islands. Parthenium infestation in agricultural lands has not reached the level of economic threshold level to reduce the yield. The impact of Parthenium on health of domestic animals was also not reported. However, from Parthenium weed infested areas, local people complained about the irritation on skin, an indication of allergenic eczematous contact dermatitis (AECD), which may be caused by Parthenium pollens and trichomes. Seema Das and Mitesh Behari (2017) reported rise in eye allergy cases in people of Andaman including Hut Bay Island, which might be due to the severe presence of Parthenium weed, however it needs to be affirmed yet. No asthma related cases were reported due to this weed in the islands. This allergic reaction of weed was ascribed to sesquiterpene lactones (SQLs) present in hairs and pollen (Towers and Mitchell 1983). The uncontrolled Parthenium in islands may enhance these health disorders in future.

Parthenium management options in islands

Preventive management: In context to Andaman & Nicobar and Lakshadweep territories, prevention of entry from one island to another island may play significant role to contain further spread of Parthenium weed. There are 572 islands in Andaman & Nicobar and 38 in Lakshadweep territory. So far, from Lakshadweep territory, Parthenium has been reported only from Minicoy Island. The main movement of materials is from mainland (Kochi, Mangalore only). There is a possibility of Parthenium entry from Bengaluru, which is connected with Agatti island via Kochi. In ANI, materials are transported from Chennai, Visakhapatnam and Kolkata to Port Blair by ships, therefore there is a need of proper quarantine of this weed from these ports. Recently, air connectivity has been extended from Delhi, Bengaluru, Hyderabad and Mumbai to Port Blair. The movement of men and materials from these places may further aid its spread in Port Blair. Therefore, opting of strict quarantine measures will certainly help to contain its further spread from the main land.

Physical removal: It is one of the easiest methods for reducing the intensity of Parthenium in infested islands of Andaman & Nicobar and Lakshadweep. Attempts have been made to uproot the weed from Minicoy Island and Harmider Bay during Parthenium Awareness Week since 2014, however, this single approach has not reduced the intensity of weed in this area at appreciable level. Nevertheless, manual method of uprooting by involving different stakeholders at regular interval before flowering of weed appears the most promising management option keeping in view of limited penetration of the weed in different isolated islands of Andaman & Nicobar and Lakshadweep.

Chemical control: There is no option to use herbicide to manage Parthenium in the islands because of banning of use of chemicals after 2018 to make the islands organic. There is option to use 15-20% saline water prepared from common salt (Singh *et al.* 1996) for controlling Parthenium in the islands. This may not be economical because of high prize of slat in absence of salt production factories owing to tropical monsoonal humid climate.

Biological control: In Harmider Bay Island (Little Andaman, South Andaman district), *Senna* species

Figure 1a. Severe Parthenium infestation in Hut Bay, South Andaman district

Figure 1b. Parthenium infestation at Sawai tee- top village of Nicobar district

Figure 2. Luxuriantly growing *Senna tora* in Hut Bay replacing Parthenium

Figure 3a. Parthenium awareness week organized at Hut Bay during 21-22 August, 2017

Figure 3b. Uprooting of Parthenium in residential areas

were found dominated on the road side (**Figure 2**). *Senna tora* has been recommended to replace Parthenium in main land of India due to its useful attributes (Sushilkumar 2009) in spite of about 23 listed competitive plants against Parthenium (Gautam *et al.* 2005). About 8 species of *Senna* have been documented from Adaman & Nicobar Islands (Reddy 2013). *Mimosa pudica* has also been found in ANI which leaf extracts (20%) application has been reported to completely (100%) inhibit the germination of Parthenium germination (Nganthoi Devi *et al.* 2013), however, this plant species cannot be recommended for replacement of Parthenium due to its invasive nature.

Biological control by host specific insect *Zygogramma bicolorata* has been considered one of the most suitable approaches for the management of Parthenium (Sushilkumar 2009 and 2014). Efforts were made in 2005 and 2006 to introduce this bioagent by sending beetle consignment to Krishi Vigyan Kendra in Port Blair from Directorate of Weed Research (Sushilkumar, personal observations) but so far there is no report of bioagent presence in the area. It is expected that if bioagent get establish in such island situations, it may help to reduce the intensity of the weed. A fresh attempt is required to introduce the bioagent in the area consulting the prediction model developed by Gharde *et al.* (2019).

Awareness and utilization approach: Local people especially tribal were not aware of the weed and its harmful effects. Awareness campaigns were conducted by organising training programmes to make people aware about the menace and management of Parthenium during Parthenium Awareness Week (16-22 August) every year since 2014 in Hut Bay, a tribal village severely infested with Parthenium. (**Figure 3a** and **3b**). The techniques of compost making by pit method was demonstrated for the utilization of uprooted weed biomass as per methods suggested by Sushilkumar *et al*. (2005). A Doordarshan programme on Parthenium weed management in Andaman & Nicobar Islands was given for the benefit of all stakeholders during 2016.

Conclusion

At present, Parthenium problem is not alarming in the Islands in comparison to main land of India, therefore, it will be easy to manage and even eradicate the weed completely. The movement of this weed in South Andaman and North and Middle Andaman districts will be easy by road and boat, therefore, more attention needs to be given by administration to check this weed in these areas. There are meagre chances of spread of Parthenium among the 16 isolated islands of Nicobar district, but immediate attention of local administration is required to contain the weed from Sawai tee-top village under Nicobar Island. Likewise, in Lakshadweep territory, sever infestation of Parthenium has been reported in Minicoy island only. Utmost attention should be given to contain the weed from this island to check further entry into other nearby islands. It is opined that eradication of Parthenium is possible from ANI because of low spread yet. Therefore, Government of ANI should come forward for its eradication programme before this invasive and obnoxious weed reach beyond the approach of such intervention.

REFERENCES

Gangaiah B. 2018. Weeds in Andaman & Nicobar Islands – A threat to crop and grassland (livestock) productivity and ecosystem, p. 51. In: *Proceedings of ISWS Golden Jubilee International Conference on "Weeds and Society: Challenges and Opportunities*", 21-24 November 2018, ICAR-Directorate of Weed Research, Jabalpur, India.

Gangaiah B, Subramani T and Singh AK. 2016. Ecological and economic weed management practices for crops / farming systems of Andaman & Nicobar Islands. Pp 59-63. In: *Integrated Farming Systems for Tropical Islands of India* (Eds: Gangaiah B and Dam Roy S), ICAR-CIARI, Port Blair.

Gautam RD. 2005. Advances in Parthenium beetle, *Zygogramma bicolorata* research and field utilization, pp. 170-176. In: *Proceedings of Second International Conference on Parthenium Management*, 5-7 December 2005. Bangalore.

Gharde Yogita, Sushilkumar and Sharma AR. 2019. Exploring models to predict the establishment of the leaf-feeding beetle *Z. bicolorata* (Coleoptera: Chrysomelidae) for the management of *P. hysterophorus* (Asteraceae: Heliantheae) in India. *Crop Protection* 122: 57–62.

GISD. 2018. Global Invasive Species Database (GISD). http://www.iucngisd.org/gisd.

Holm LG, Plucknett DL, Panchu JV and Herberger JP. 1997. The world's worth weeds. Honolulu Univ**.** Press. http://en.wikipedia.org/wiki/herbalism (accessed on 15-02-2019).

Jayanth KP. 1987. Introduction and establishment of *Zygogramma bicolorata* on *Parthenium hysterophorus* in Bangalore, India. *Current Science* **56**: 310–311.

Mahadevappa M and Ramaiah H. 1988. Pattern of replacement of *Parthenium hysterophorus* plants by *Senna sericea* in waste lands. *Indian Journal of Weed Science* **20**: 83–85.

Mitchell JC and Calnan CD. 1978. Scourge of India. Parthenium dermatitis. *International Journal of Dermatology* **17**: 303–304.

Nganthoi Devi Y, Ghanapyari K, Dutta BK, Ray DC and Irabanta Singh N. 2013. Parthenium infestation and evaluation of botanicals and bio agents for its management. *Indian Journal of Weed Science* **45**(1): 62–67.

Prem Kishor, Ghosh AK, Sureendra Singh and Maurya BR. 2010. Potential use of Parthenium (*Parthenium hysterophorus* L.) in agriculture. *Asian Journal of Agricultural Research* **4**(4): 220–225.

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

Rathore SS, Krose N, Naro M, Shekhawat K and Bhatt BP. 2012. Weed management through salt application: an indigenous method for shifting cultivation areas, Eastern Himalaya, India. *Indian Journal of Traditional Knowledge* **11**: 354–357.

Reddy CS. 2013. Flora of North Andaman Islands, India. **6:** 111–208. In: *Biodiversity in India* (Eds: Pullaiah T and Reddy K J), Regency Publications, New Delhi.

Seema Das and Mitesh Behari. 2017. Pattern of OPD attendance of paediatric patients in ophthalmology OPD in a tertiary referral hospital of Andaman and Nicobar Islands. *International Journal of Contemporary Medical Research* **4**(12):1–3.

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

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

Sushilkumar. 2014. Spread, menace and management of Parthenium. *Indian Journal of Weed Science* **46**(3): 205–219.

Sushilkumar and Varshney Jay 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. pp. 114–19. In: *2nd International Conference on Parthenium Management*. Bangalore. December 5-7, 2005.

Indian Journal of Weed Science **52**(3): 204–210, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Diversity is the key for successful agroecological weed management

Stéphane Cordeau*[1], Guillaume Adeux[1] and Violaine Deytieux[2]

[1]*Agroécologie, AgroSup Dijon, INRAE, University Bourgogne, University Bourgogne Franche-Comté, F-21000 Dijon, France*

[2]*INRAE, UE115 Domaine Expérimental d'Epoisses, F-21000 Dijon, France*

**Email: stephane.cordeau@inrae.fr*

Article information

DOI: 10.5958/0974-8164.2020.00039.8

Type of article: Review article

Received : 28 May 2020
Revised : 12 August 2020
Accepted : 14 August 2020

Key words

Agroecology

CA-SYS platform

Cropping system

Evenness

Community

Yield loss

ABSTRACT

Reconciling crop productivity and biodiversity maintenance is one of the main challenges of agriculture worldwide. Weed management is recognized to be a key point for ecological intensification in agriculture because weeds can generate severe yield losses but also represent the base of agricultural trophic networks. Research in weed science has often opposed two different perceptions of weeds. Low within-field weed diversity and abundance has either been considered as a sign of efficient weed management or an erosion of the agroecosystem services provided by weeds. However, a recent study in grain-based systems in France highlighted the potential benefits of weed diversity in mitigating crop yield losses. Major yield losses may simply arise from the dominance of a few competitive species. A higher diversity of traits (characteristics) within the weed community should induce complementarity in resource use (light, water, nitrogen *etc.*) and alleviate weed:crop competition. Thus, weed scientists should try to confirm this relationship in different production situations (e.g. floristic contexts, pedoclimates, cropping systems) and then identify cropping systems which promote weed evenness, either from a taxonomic or functional point of view. Weeding operations should exclusively target competitive and dominant species. However, current weed control practices do not allow to target a specific species in a complex community. Therefore, future studies need to identify if weed diversity could rather be indirectly promoted by diversifying weed management tools, which ought to limit weed density/biomass. The CA-SYS platform (INRAE, Dijon, France) is a unique site in Europe to experiment biodiversity-based forms of agriculture, including a diversity of weed management strategies. The overarching objective of the CA-SYS platform is to design and test the feasibility and performances of pesticide-free agriculture which resorts to (cropped and wild) biodiversity in support of production.

INTRODUCTION

Intensive use of herbicides, nitrogen and tillage has generated a massive decline of within-field weed diversity (Albrecht *et al.* 2016). A meta-analysis of 53 studies concluded that weed species richness decreased by 20% on average across Europe after the end of World War II (Richner *et al.* 2015). In Britain, weeds are considered as the most threatened group of plants (Still and Byfield 2007). In France, Fried *et al.* (2009) observed a 42% decline in weed species richness and a 67% decline in total weed density at the field level between 1970 and 2000. This massive decline in weed diversity may be viewed as a sign of efficient weed management and crop productivity maintenance. Weed management is recognized to be a key point for ecological intensification in agriculture (Petit *et al.* 2015) because certain weeds can generate severe yield losses (Oerke 2006), which has justified their control, but also provide ecosystem services beneficial to crop production. However, weed management in arable crops currently mainly relies on herbicides. In France, herbicides represented 43.8% of total pesticides used in 2014 (European Crop protection, http://www.ecpa.eu/). Reducing the reliance of cropping systems on herbicide use is promoted throughout Europe (e.g. EU legislation and French ECOPHYTO plan) since the negative impacts of intensive agriculture on environment and health have been highlighted (Soule *et al.* 1990, Stoate *et al.* 2009). Therefore, there is an urgent need to move towards more sustainable weed management strategies that are much less reliant on herbicide use while preserving crop productivity and biodiversity.

Integrated weed management (IWM) suggests that many different weed management tools can be used in an integrated way to manage weeds while reducing herbicide reliance, which relies on knowledge of cropping system effects on weed dynamics (Swanton *et al.* 2008). Diversified cropping systems integrating a diverse suite of management tools coherently combined at the cropping system scale have been shown to provide efficient long-term weed management while significantly reducing herbicide reliance (Adeux *et al.* 2017, Colbach and Cordeau 2018, Adeux *et al.* 2019a, Yvoz *et al.* 2020). In addition, IWM cropping systems may reconcile agricultural crop production, low herbicide use and weed biodiversity (Petit *et al.* 2015) and be more energy efficient (Lechenet *et al.* 2014, Lechenet *et al.* 2017a). A shift from IWM to agro-ecological or ecologically intensive approaches (Petit *et al.* 2018) should allow to further reduce herbicide reliance. Nevertheless, such a shift will require the status of weeds to be reconsidered (Wilson *et al.* 2009) and a greater understanding of weed:crop interference in complex weed communities (Storkey and Neve 2018). As a matter of fact, the importance of weed diversity in mitigating yield losses has been identified as one of the top five research priorities in current weed science (Neve *et al.* 2018).

Yield loss is due to the dominance of a few competitors

Weeds interact directly with crops by competition for water and mineral resources (Zimdahl 2004), allelopathy (Kadioglu *et al.* 2005) and parasitism (Parker 2009). In weed science, weed:crop interactions have mainly been studied in neighborhood designs considering only two species at a time, *i.e.* the crop and a specific weed species. In such designs, the crop and the weed are grown either together in mixtures or separately in monocultures (Wilson *et al.* 1990, Larson *et al.* 2016). Monocultures allow the assessment of a species maximum productivity in absence of competition (*e.g.* weed-free yield) whereas mixtures encompass the competitive effect of the weed on the crop, and vice versa. The measured outcome is usually plant biomass, considering biomass is strongly related with overall fitness (Weiner 1990). According to ecological theory, weed:crop competition should occur when one of the resources is present in limited supply (Lang and Benbow 2013). Competitive dominants usually express traits related to resource uptake (Novoplansky 2009) and weeds showing competitive trait values tend to generate more biomass and therefore, compete more intensely with the crop (Wilson *et al.* 1990).

Studies focusing on pairwise competitive interactions have provided little insight on the effect of diversified weed communities on crop performance. Indeed, crops are often confronted to a diversity of weed species (Quinio *et al.* 2017, Yvoz *et al.* 2020) which may interact with one another (Clements *et al.* 1994). More recently, increased attention has been paid to the effect of weed diversity in mitigating crop yield losses due to weeds (Pollnac *et al.* 2009, Ferrero *et al.* 2017, Storkey and Neve 2018, Gonzalez-Andujar *et al.* 2019). Adeux *et al.* (2019b) demonstrated in grain-based systems that not all weed communities generate significant crop yield losses and that important crop yield losses were associated to the dominance of a few competitive species capable of producing high levels of biomass (*i.e.* low weed diversity). Out of the six identified weed communities, the authors showed that only four generated significant yield losses (19 to 56%) in unweeded zones. Diversified weed communities limited crop yield losses associated to competitive dominants while potentially maximizing ecosystem services provided by subordinate species.

Low weed diversity may arise because of oversimplified and redundant weed management (**Figure 1**). Recent surveys have shown that the majority of farmers were reluctant to incomplete weed management (Jabbour *et al.* 2014, Kings 2014, Moss 2017), possibly due to a belief of exponential weed dynamics even in diversified IWM systems. Research is needed to highlight that incomplete weeding in a given year can be compensated over time by a diversified crop rotation and a suite of weed management tactics (Adeux *et al.* 2019a). Greater knowledge of weed biology and ecology could allow farmers to better target competitive dominants and ease their fear of the remaining subordinates.

Weed evenness is promoting by cropping system diversity

Farmers dispose of a wide range of options to manage weeds without resorting to herbicides. Weed management tools can be classified in preventive, cultural, mechanical, biological and chemical methods (Barzman *et al.* 2015). Preventive methods focus on keeping weeds out of the field or spreading within a field (*e.g.* composting farmyard manure, cleaning equipment that could transport weed seeds, management of field margins (Cordeau *et al.* 2012),

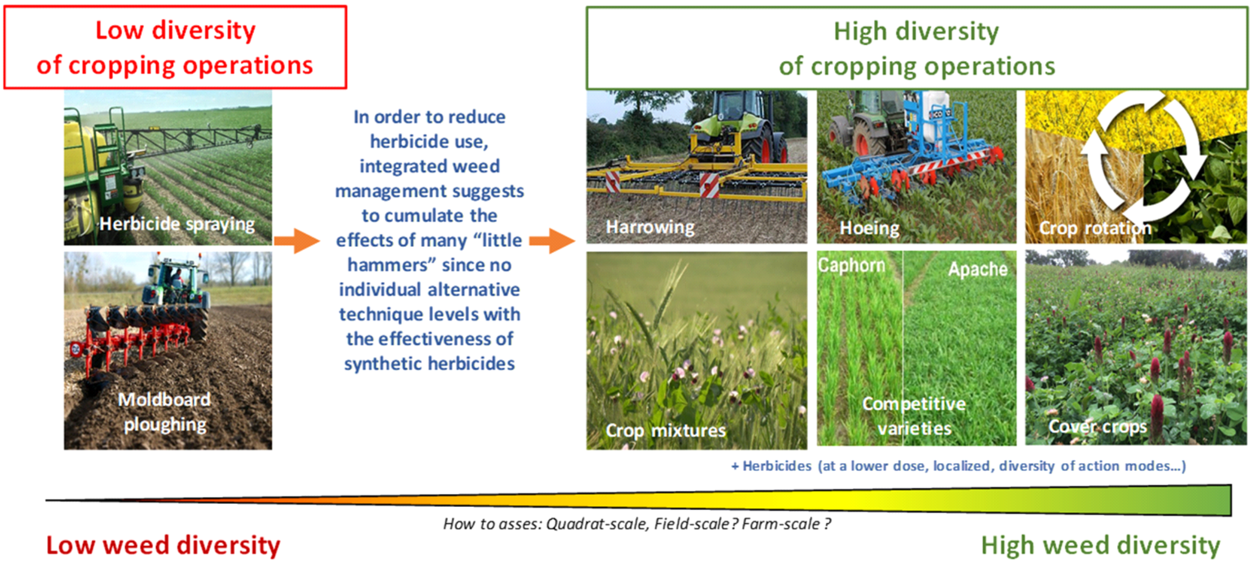

Figure 1. Effects of cropping systems diversification on weed diversity (Copyright: Adeux Guillaume © INRAE 2020)

…). Cultural methods include all practices which can confer the crop a competitive advantage over weeds (*e.g.* crop rotation, increased crop density, optimum nutrient management, delayed sowing, competitive crop cultivars…). Mechanical methods encompass all practices that disrupt germination and destroy the plant (*e.g.* tillage (Cordeau *et al.* 2017), mechanical weeding (Melander *et al.* 2005)…). Chemical methods mainly refer to the direct use of herbicides (*e.g.* timely scouting, proper weed identification, proper conditions of application, rotation of herbicide mode of action…). Biological methods refer to any living organisms used to target weeds (Cordeau *et al.* 2016, Petit *et al.* 2018).

None of these tools allow to match with the effectiveness of synthetic herbicides. Hence, the mere substitution of herbicides by a unique alternative tool is not conceivable. To reduce herbicide reliance and maintain crop productivity, integrated weed management seeks to optimize the synergy between a diverse set of weed management tools coherently combined at the cropping system scale (Swanton and Weise 1991). Sustainable weed management strategies should combine all biological, chemical, cultural, and mechanical methods ("many little hammers") that allow the reduction of weed emergence, weed growth and weed seed production (Liebman and Gallandt 1997). Cropping system diversification can be carried out at both the annual and pluri-annual scales through a diversification of the crop rotation and associated weed management tools (Wezel *et al.* 2014).

Cropping systems which rely on a combination of a well-balanced crop rotation and a diverse set of weed management tools coherently combined at the cropping scale, rather than intensive use of herbicides (*i.e.* one of the main causes in the decline of weed diversity), appear as a promising solution to increase weed diversity while maintaining crop productivity (Ulber *et al.* 2009, Adeux *et al.* 2019a). Increasing crop functional diversity could allow a greater tolerance to weeds in a given year through the prevention of explosive weed dynamics at the cropping system scale (Adeux *et al.* 2019a).

Experimenting pesticide-free biodiversity-based systems

Recent research efforts have led to significant advances on how to manage weeds in agricultural landscapes. For a long time, agronomists have designed and tested cropping systems on long-term cropping system experiments. These cropping system experiments, in contrast to factorial experiments testing one or few practices, aim to design and test the interactive effect of coherent combinations of numerous management factors implemented to fulfill predefined objectives under specific constraints (Drinkwater 2002, Lechenet *et al.* 2017b). Following the same philosophy as cropping system experiments, agroecological system experiments (Petit *et al.* In press) also adopt a systemic approach, but include the design of the spatio-temporal arrangement and management of fields and semi-natural habitats at the farm level. Thus, an agroecological system represents a coherent landscape design strategy: a mosaic of adjacent fields with diverse cropping systems and a network of semi-natural habitats.

Since summer 2018, the CA-SYS platform has been experimenting a diversity of pesticide-free grain-based agroecological systems (wheat, barley, rapeseed, pea, soybean, fababean, *etc.*) on 125 ha divided into 42 plots of 2.5 ha on average (**Figure 2**), within the INRAE 'Domaine d'Epoisses' experimental unit (located close to Dijon, France). The overarching objective of the CA-SYS platform is to design and test the feasibility and performances of pesticide-free agriculture using (cropped and wild) biodiversity in support of production, *i.e.* biodiversity-based forms of agriculture (Cordeau *et al.* 2015). Therefore, all pesticides including those authorized in organic agriculture or bioproducts are also prohibited within the CA-SYS platform.

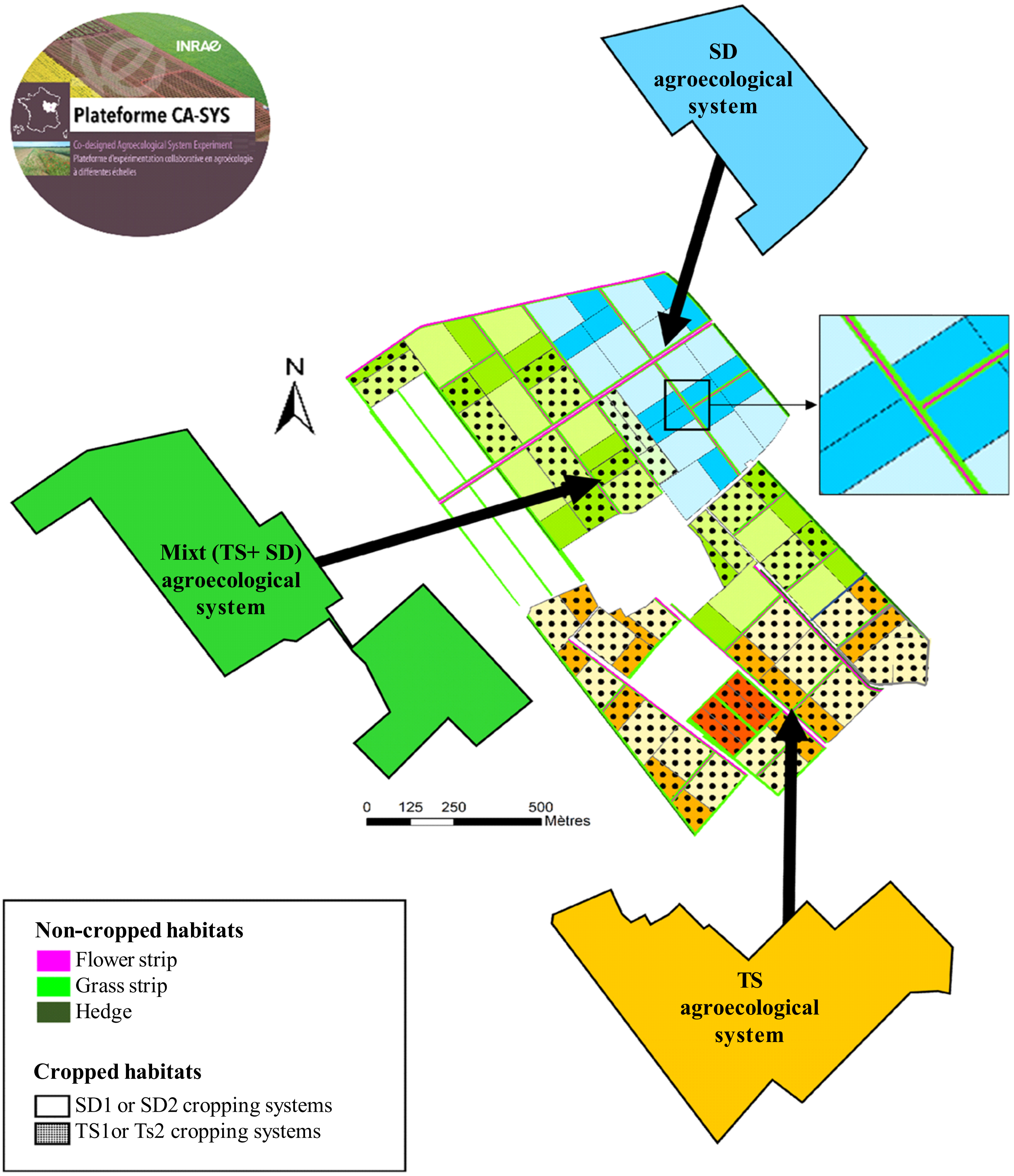

Figure 2. Experimental design of the CA-SYS platform (INRAE, Dijon, FR) testing four pesticide-free cropping systems nested within three agroecological systems (blue: no-till and no-plow systems, orange: plowing-based systems; green: mix of both options) (copyright: Violaine Deytieux and Stéphane Cordeau © INRAE 2020)

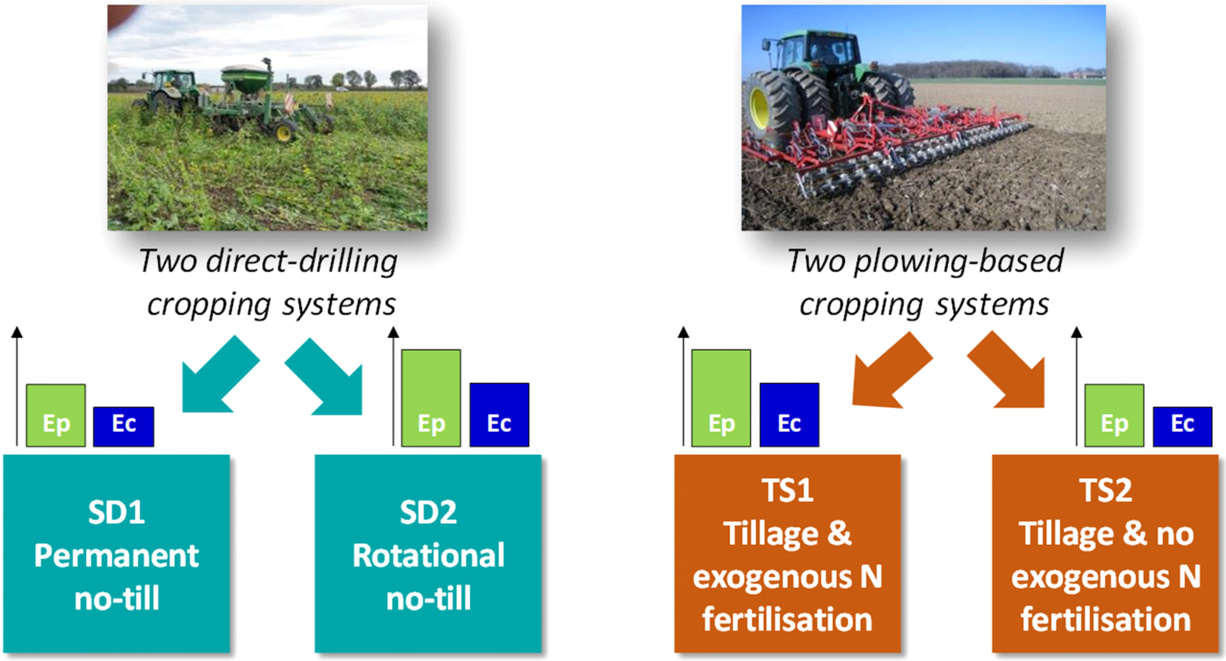

Figure 3. Four pesticide-free cropping systems tested in the CA-SYS Platform (INRAE Dijon, FR) exploring two agricultural pathways. Ep: Energy produced; Ec: Energy consumed to produce. The Ep/Ec ratio is the energy efficiency. (Copyright: Violaine Deytieux and Stéphane Cordeau © INRAE 2020)

The management of each plot is governed by a body of decision rules which vary according to the constraints and objectives assigned to each cropping system. Therefore, the practices are not fixed but adaptive and are implemented following the decision rules according to the observed conditions of the plot (soil humidity, pest pressure, legacy of past crops, etc.). Four pesticide-free cropping systems are tested (**Figure 3**) in line with two relevant agricultural pathways to address agroecological challenges: the first, inspired by organic agriculture, is a plowing-based system (occasional plowing, false seedbed operations, mechanical weeding, hereafter named TS); the other, inspired by conservation agriculture, is a no-plow, direct-seeded system maximizing soil cover (named SD). These two options mobilize a wide diversity of crops in time (at the scale of crop succession) and space (mixtures of species and/or varieties). Within the two pathways (*i.e.* TS and SD), two cropping systems are tested. TS1 allows the use of exogenous N fertilizers whereas TS2 targets auto fertility and bans the use of exogenous N fertilizers. In accordance with the cropping system approach, crop rotation and associated practices differ between TS1 and TS2. SD1 represents a permanent no-till system whereas SD2 allows the use of superficial tillage if necessary, no more than once a year before crop sowing to terminate weeds, crop volunteers or cover crops. No P and K fertilizers are applied in any of the crops of the four cropping systems (i.e. TS1, TS2, SD1 and SD2).

To assess the cropping system and agroecological system performances, study the ecological processes underlying the effect of practices, and describe the transition, the initial state was characterized and observations are performed on a regular basis in fixed zones within plots and semi-natural habitats. For instance, weeds are assessed twice a year in all plots, before and after weeding, and yield loss due to weeds is estimated by biomass sampling of weeds and crops at crop flowering (Adeux *et al.* 2019a).

Conclusion

Weed management is recognized to be a key point for ecological intensification in agriculture. Weeds can generate important crop yield losses. However, yield losses are often due to the dominance of certain highly competitive weed species. High dominance of a few competitors is often due to the oversimplification of cropping systems. Diversifying cropping system both at the spatial and temporal scales 'keeps weeds guessing', makes the field an unpredictable habitat for weeds and thus reduces the probability of dominated weed communities, thereby preventing important yield losses. Even if biodiversity-based options to manage weeds exist, there is still an urgent need to design and test ambitious agroecological weed management strategies. The CA-SYS platform is a unique site tackling this challenge, opening avenues for agroecological weed management and should provide insights for future research.

ACKNOWLEDGEMENTS

The authors would like to thank all members of the INRAE research station "Domaine d'Epoisses" whom helped to design the experiment and whom carried it out with dedication. The CA-SYS platform is leading by Stéphane Cordeau and Violaine Deytieux (INRAE). The author wish to acknowledge financial support from the French project CoSAC (ANR-15-CE18-0007), the French program "Investissements d'Avenir", the project ISITE-BFC (contract ANR-15-IDEX-03) and the project DEPHY EXPE ABC « Agroécologie en Bourgogne et Région Centre » (Action of the Ecophyto plan, Ministry of Agriculture, Ecology, Health and Research, with technical and financial support from the Office Français de la Biodiversité).

REFERENCES

Adeux G, Giuliano S, Cordeau S, Savoie J-M, Alletto L. 2017. Low-input maize-based cropping systems implementing IWM match conventional maize monoculture productivity and weed control. *Agriculture* **7**: 74.

Adeux G, Munier-Jolain N, Meunier D, Farcy P, Carlesi S, Barberi P, Cordeau S. 2019a. Diversified grain-based cropping systems provide long-term weed control while limiting herbicide use and yield losses. *Agronomy for Sustainable Development* **39**: 42.

Adeux G, Vieren E, Carlesi S, Bàrberi P, Munier-Jolain N, Cordeau S. 2019b. Mitigating crop yield losses through weed diversity. *Nature Sustainability* **2**: 1018–1026.

Albrecht H, Cambecèdes J, Lang M, Wagner M. 2016. Management options for the conservation of rare arable plants in Europe. *Botany Letters* **163**: 389–415.

Barzman M, Bàrberi P, Birch ANE, Boonekamp P, Dachbrodt-Saaydeh S, Graf B, Hommel B, Jensen JE, Kiss J, Kudsk P, Lamichhane JR, Messéan A, Moonen A-C, Ratnadass A, Ricci P, Sarah J-L, Sattin M. 2015. Eight principles of integrated pest management. *Agronomy for Sustainable Development* **35**: 1199–1215.

Clements DR, Weise SF, Swanton CJ. 1994. Integrated weed management and weed species diversity. *Phytoprotection* **75**: 1–18.

Colbach N, Cordeau S. 2018. Reduced herbicide use does not increase crop yield loss if it is compensated by alternative preventive and curative measures. *European Journal of Agronomy* **94**: 67–78.

Cordeau S, Deytieux V, Lemanceau P, Marget P. 2015. Towards the establishment of an experimental research unit on Agroecology in France. *Aspects of applied biology* 128: Valuing Long-Term sites and Experiments for Agriculture and Ecology: 271–273.

Cordeau S, Petit S, Reboud X, Chauvel B. 2012. The impact of sown grass strips on the spatial distribution of weed species in adjacent boundaries and arable fields. *Agriculture Ecosystems & Environment* **155**: 35–40.

Cordeau S, Smith RG, Gallandt ER, Brown B, Salon P, DiTommaso A, Ryan MR. 2017. Timing of tillage as a driver of weed communities. *Weed Science* **65**: 504–514.

Cordeau S, Triolet M, Wayman S, Steinberg C, Guillemin J-P. 2016. Bioherbicides: Dead in the water? A review of the existing products for integrated weed management. *Crop Protection* **87**: 44–49.

Drinkwater LE. 2002. Cropping Systems Research: Reconsidering Agricultural Experimental Approaches. *HortTechnology* **12**: 355–361.

Ferrero R, Lima M, Davis AS, Gonzalez-Andujar JL. 2017. Weed Diversity Affects Soybean and Maize Yield in a Long Term Experiment in Michigan, USA. *Frontiers in Plant Science* **8**: 236.

Fried G, Petit S, Dessaint F, Reboud X. 2009. Arable weed decline in Northern France: Crop edges as refugia for weed conservation? *Biological Conservation* **142**: 238–243.

Gonzalez-Andujar JL, Aguilera MJ, Davis AS, Navarrete L. 2019. Disentangling weed diversity and weather impacts on long-term crop productivity in a wheat-legume rotation. *Field Crops Research* **232**: 24–29.

Jabbour R, Zwickle S, Gallandt ER, McPhee KE, Wilson RS, Doohan D. 2014. Mental models of organic weed management: Comparison of New England US farmer and expert models. *Renewable Agriculture and Food Systems* **29**: 319–333.

Kadioglu I, Yanar Y, Asav U. 2005. Allelopathic effects of weeds extracts against seed germination of some plants. *Journal of environmental biology/Academy of Environmental Biology, India* **26**: 169–173.

Kings D. 2014. Farmers' understandings of weeds and herbicide usage as environmental influences on agricultural sustainability. *Journal of Environmental Protection* **5**: 923.

Lang JM, Benbow ME. 2013. Species interactions and competition. *Nature Education Knowledge* **4**: 8.

Larson AAD, Renz MJ, Stoltenberg DE. 2016. Effects of Giant Foxtail (Setaria faberi) and Yellow Foxtail (Setaria pumila) Competition on Establishment and Productivity of Switchgrass. *Weed Science* **64**: 129–136.

Lechenet M, Bretagnolle V, Bockstaller C, Boissinot F, Petit M-S, Petit S, Munier-Jolain N. 2014. Reconciling pesticide reduction with economic and environmental sustainability in arable farming. *PlosOne* **9**: e97922.

Lechenet M, Dessaint F, Py G, Makowski D, Munier-Jolain N. 2017a. Reducing pesticide use while preserving crop productivity and profitability on arable farms. *Nature Plants* **3**: 17008.

Lechenet M, Deytieux V, Antichi D, Aubertot J-N, Bàrberi P, Bertrand M, Cellier V, Charles R, Colnenne-David C, Dachbrodt-Saaydeh S. 2017b. Diversity of methodologies to experiment Integrated Pest Management in arable cropping systems: Analysis and reflections based on a European network. *European Journal of Agronomy* **83**: 86–99.

Liebman M, Gallandt E, 1997. Many little hammers: Ecological management of crop-weed interactions. In: LE, J (Ed.), Ecology in agriculture. Academic Press, New York, pp. 291–343.

Melander B, Rasmussen IA, Bàrberi P. 2005. Integrating physical and cultural methods of weed control-examples from European research. *Weed Science* **53**: 369–381.

Moss S. 2017. Black-grass (Alopecurus myosuroides): Why has this Weed become such a Problem in Western Europe and what are the Solutions? *Outlooks on Pest Management* **28**: 207–212.

Neve P, Barney JN, Buckley Y, Cousens RD, Graham S, Jordan NR, Lawton-Rauh A, Liebman M, Mesgaran MB, Schut M, Shaw J, Storkey J, Baraibar B, Baucom RS, Chalak M, Childs DZ, Christensen S, Eizenberg H, Fernández-Quintanilla C, French K, Harsch M, Heijting S, Harrison L, Loddo D, Macel M, Maczey N, Merotto Jr A, Mortensen D, Necajeva J, Peltzer DA, Recasens J, Renton M, Riemens M, Sønderskov M, Williams M. 2018. Reviewing research priorities in weed ecology, evolution and management: a horizon scan. *Weed Research* **58**: 250–258.

Novoplansky A. 2009. Picking battles wisely: plant behaviour under competition. *Plant, Cell & Environment* **32**: 726–741.

Oerke EC. 2006. Crop losses to pests. *The Journal of Agricultural Science* **144**: 31–43.

Parker C. 2009. Observations on the current status of Orobanche and Striga problems worldwide. *Pest Management Science* **65**: 453–459.

Petit S, Cordeau S, Chauvel B, Bohan D, Guillemin J-P, Steinberg C. 2018. Biodiversity-based options for arable weed management. A review. *Agronomy for Sustainable Development* **38**.

Petit S, Deytieux V, Cordeau S. In press. Landscape-scale approaches for designing and assessing biodiversity-based agricultural systems enhancing biological pest control. *Environmental monitoring and assessment*.

Petit S, Munier-Jolain N, Bretagnolle V, Bockstaller C, Gaba S, Cordeau S, Lechenet M, Mézière D, Colbach N. 2015. Ecological intensification through pesticide reduction: weed control, weed biodiversity and sustainability in arable farming. *Environmental Management* **56**: 1078–1090.

Pollnac FW, Maxwell BD, Menalled FD. 2009. Weed community characteristics and crop performance: a neighbourhood approach. *Weed Research* **49**: 242–250.

Quinio M, De Waele M, Dessaint F, Biju-Duval L, Buthiot M, Cadet E, Bybee-Finley AK, Guillemin J-P, Cordeau S. 2017. Separating the confounding effects of farming practices on weeds and winter wheat production using path modelling. *European Journal of Agronomy* **82**: 134–143.

Richner N, Holderegger R, Linder HP, Walter T. 2015. Reviewing change in the arable flora of Europe: a meta-analysis. *Weed Research* **55**: 1–13.

Soule J, Carré D, Jackson W, 1990. Ecological impact of modern agriculture. In: Carroll, C, Vandermeer, J, Rosset, P (Eds.), Agroecology. McGraw-Hill Publishing Co, New York, pp. 165–188.

Still K, Byfield A. 2007. New priorities for arable plant conservation. *Plantlife, Salisbury*.

Stoate C, Baldi A, Beja P, Boatman ND, Herzon I, van Doorn A, de Snoo GR, Rakosy L, Ramwell C. 2009. Ecological impacts of early 21st century agricultural change in Europe - A review. *Journal of Environmental Management* **91**: 22–46.

Storkey J, Neve P. 2018. What good is weed diversity? *Weed Research* **58**: 239–243.

Swanton CJ, Mahoney KJ, Chandler K, Gulden RH. 2008. Integrated Weed Management: Knowledge-Based Weed Management Systems. *Weed Science* **56**: 168–172.

Swanton CJ, Weise SF. 1991. Integrated weed management - the rationale and approach. *Weed Technology* **5**: 657–663.

Ulber L, Steinmann H-H, Klimek S, Isselstein J. 2009. An on-farm approach to investigate the impact of diversified crop rotations on weed species richness and composition in winter wheat. *Weed Research* **49**: 534–543.

Weiner J. 1990. Asymmetric competition in plant populations. *Trends in Ecology & Evolution* **5**: 360–364.

Wezel A, Casagrande M, Celette F, Vian J-F, Ferrer A, Peigné J. 2014. Agroecological practices for sustainable agriculture. A review. *Agronomy for Sustainable Development* **34**: 1–20.

Wilson BJ, Cousens R, Wright KJ. 1990. The response of spring barley and winter wheat to *Avena fatua* population density. *Annals of Applied Biology* **116**: 601–609.

Wilson R, Hooker N, Tucker M, LeJeune J, Doohan D. 2009. Targeting the farmer decision making process: a pathway to increased adoption of integrated weed management. *Crop Protection* **28**: 756–764.

Yvoz S, Petit S, Biju-Duval L, Cordeau S. 2020. A framework to type crop management strategies within a production situation to improve the comprehension of weed communities. *European Journal of Agronomy* **115**: 126009.

Zimdahl RL, 2004. Weed-crop competition - A review. Balckwell Publishing, Oxford.

Indian Journal of Weed Science **52**(3): 211–216, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Herbicides and herbicide combinations for management of *Leptochloa chinensis* in wet-seeded rice

Lekshmi Sekhar*, M. Ameena and Nimmy Jose[1]

Department of Agronomy, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala 695522, India

[1]Rice Research Station, Moncompu, Alappuzha, Kerala 688503, India

**Email: lekshmisekhar1@gmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00040.4

Type of article: Research article

Received : 19 March 2020
Revised : 22 July 2020
Accepted : 25 July 2020

Key words

Chinese sprangletop

Herbicides

Ready-mix combination

Tank mix combination

Weeds

Wet seeded rice

ABSTRACT

An experiment was conducted to evaluate the efficiency of various herbicides for the management of chinese sprangletop (*Leptochloa chinensis*) at Integrated Farming System Research Station, Karamana, Thiruvananthapuram of Kerala Agricultural University, India during *Kharif* (rainy season) 2018 and 2019. Grass weeds were the most dominant weed species followed by broad-leaf weeds and sedges during both the crop seasons. The present study revealed that fenoxaprop-p-ethyl at 60 g/ha was the most effective herbicide against *L. chinensis* followed by cyhalofop-butyl at 80 g/ha. Dry matter production of *L. chinensis* was lower in sole application of fenoxaprop-p-ethyl at 60 g/ha and cyhalofop-butyl at 80 g/ha compared to their tank mix combination with bispyribac-sodium at 25 g/ha during both the years. Ready-mix combination of penoxsulam + cyhalofop-butyl (6% OD) at 150 g/ha was very effective in managing the complex spectrum of weeds however, it was not effective in managing *L. chinensis* compared to other herbicidal treatments. Application of bispyribac-sodium alone at 25 g/ha was not effective in controlling *L. chinensis* resulted in lower weed control efficiency of 37 and 48% during 2018 and 2019, respectively. Tank mix application of bispyribac-sodium with fenoxaprop-p-ethyl (at 25 + 60 g/ha) or cyhalofop-butyl (at 25 + 80 g/ha) recorded the least total dry matter production of weeds. All the tested herbicides and the herbicide combinations increased the grain yield compared to unweeded control during both the years.

INTRODUCTION

Chinese sprangletop or Red sprangletop scientifically known as *Leptochloa chinensis* (L.) Nees., is one of the most problematic grass weeds in rice. It is a strongly tufted, annual or short-lived perennial C_4 grass with glabrous leaves and fibrous roots. Its flowering culms are erect or ascending from a branching base and the inflorescence forms an open panicle of 15-60 cm long with numerous, slender flexuous branches (CABI 2019).

L. chinensis was earlier confined as a weed specific to the alkaline soils of Kerala and considered as an indicator plant for alkaline conditions. Of late, it has become problematic due to the shift in weed flora in the paddy fields (Jacob 2017) and heavy infestation of this weed has been reported from major rice tracts of Kerala. The weed has been spreading fast due to its prolific seed production capacity. Its ability to withstand waterlogged conditions as well as drained and moist conditions makes it a problem weed in rice (Galinato *et al*. 1999). It competes with rice from the middle of the vegetative stage to the grain filling stage and one-third loss in the yield has been reported from the plots which had 40 red sprangletop plants/m^2 (Jacob 2014).

Chemical weed control is probably the only feasible alternative in wet seeded rice. However, continuous use of a single herbicide is not effective in eliminating the weed menace in context of emerging weed shifts. Continuous use of bispyribac-sodium since 1998 onwards to control barnyard grass has resulted in a shift of dominance by *L. chinensis* in wetland rice fields of Sri Lanka (Marambe 2002). In addition, reliance on a single herbicide may result in the evolution of herbicide resistance. Continuous use of same herbicide or herbicides with a similar mode of action will lead to the development of herbicide resistance (Duary 2008). To widen the spectrum of weed control and to avoid build-up of herbicide resistance, the use of compatible mixtures of novel herbicides by tank mixing is a viable economic option. As *L. chinensis* has become a major weed in the majority of rice growing tracts of Kerala such as Kole, Kuttanad and Palakkad, formulating an effective and economic management strategy is highly essential before its population reaches alarming proportions.

MATERIALS AND METHODS

Field experiments to evaluate the performance of herbicides and herbicide combinations for the management of *L. chinensis* were carried out during the *Kharif* (rainy) seasons of 2018 and 2019 at the Integrated Farming System Research Station, Karamana, Thiruvananthapuram of Kerala Agricultural University, India. The field was situated geographically at 8^0 47' N latitude and 76^0 96' E longitude. The soil in the experimental field was sandy clay loam (62% sand, 10% silt, and 28% clay) with a pH of 4.84, 225.8 kg available N, 32 kg available P, and 450.9 kg available K per hectare during 2018. The experiment was conducted in another field of the station during 2019 with a pH of 5.86, 175.6 kg available N, 29 kg available P, and 377.66 kg available K per hectare. Rice variety '*Uma*' (*MO 16*) (115 - 120 days duration) seeds at 100 kg/ha (200 g/plot) were broadcasted in the individual plots of 20 m^2 (5 x 4 m) size. The treatments included cyhalofop-butyl at 80 g/ha, penoxsulam + cyhalofop-butyl (6% OD) – ready-mix formulation at 150 g/ha, cyhalofop-butyl + carfentrazone-ethyl at 80 + 200 g/ha, bispyribac-sodium at 25 g/ha, bispyribac-sodium + cyhalofop-butyl at 25 + 80 g/ha, bispyribac-sodium + fenoxaprop-p-ethyl at 25 + 60 g/ha, fenoxaprop-p-ethyl at 60 g/ha, stale seedbed *fb* glyphosate + oxyfluorfen *fb* cyhalofop-butyl + carfentrazone-ethyl at 800 + 150 *fb* 80 + 200 g/ha, hand weeding twice at 20 and 45 days after sowing and an untreated control. The treatments were replicated thrice with randomized block design and the plot size adopted was 20 m^2 (5 x 4 m). All the herbicides were applied as post-emergence at 18 DAS, when weeds reached 3-4 leaf stages. The spray volume used in the study was 500 L/ha and herbicides were sprayed with a hand operated knapsack sprayer fitted with a flat-fan nozzle. In stale seedbed treatment, the fields were drained and allowed the weed seeds to germinate for 15 days followed by chemical weeding with glyphosate at 800 g/ha + oxyfluorfen at 150 g/ha at 18 days after land preparation (DALP), followed by flooding after two days until sowing of the crop. Pre-germinated rice seeds were sown after draining the field and cyhalofop-butyl + carfentrazone-ethyl at 80 + 200 g/ha was applied later at the 3-4 leaf stage of weed.

The crop was fertilized with a recommended dose of FYM (5 t/ha) and incorporated at the time of the last ploughing. Fertilizers were applied at 90:45:45 kg/ha N:P:K (KAU 2016). Observations on weed density and weed dry weight for total weeds and *L. chinensis* were recorded separately using a quadrate of size 50 x 50 cm (0.25 m^2) randomly at two sites in each plot at 15, 30, 45 days after treatment application (DATA). Data on weed count and biomass, which showed wide variation, were subjected to square root transformation. While the ANOVA indicated significant treatment effects, means were separated at $p<0.05$ and adjusted with Fisher's protected least significant difference (LSD) test. Weed control efficiency (WCE) was computed separately for *L. chinensis* and total weeds by using weed dry weight. Yield attributing characters like panicles/m^2, grains/panicle, percentage of filled grains and 1000 grain weight were recorded at harvest by placing the quadrate (0.25 x 0.25 m) in each plot. The data generated from the experiments were subjected to analysis of variance of RBD using the statistical package WASP (Web-Based Agricultural Statistics Software Package).

RESULTS AND DISCUSSION

Weed flora and density

Grass weeds were the most dominant weed species followed by broad-leaf weeds and sedges during both the crop seasons. The grass weeds comprised of *Leptochloa chinensis, Echinochloa colona*, and *Isachne miliacea.* The major broad-leaf weeds were *Sphenocleaa zeylanica*, *Bergia capensis*, *Monochoria vaginalis*, *Limnocharis flava*, *Ludwigia perennis, Alternnathera philoxeroides* and *Lindernia parviflora*. The sedges present were *Cyperus iria*, *Cyperus difformis* and *Fimbristylis miliacea.*

At 45 DATA, grass weeds constituted 89% during 2018 and 75% during 2019 (**Table 1**). Out of this, *L. chinensis* constituted 81% during 2018 and 56% during 2019 (**Table 2**). Density of *L. chinensis* was zero in fenoxaprop-p-ethyl at 60 g/ha sprayed plots at 15 DATA during both the years and provided very good control at 30 and 45 DATA during both the years (**Table 3**). This result was closely confirmed with the findings of Jacob (2014), who reported fenoxaprop-p-ethyl as the most effective herbicide against *L. chinensis* and resulted in 100% control at 30 and 60 DAS. Application of bispyribac-sodium at 25 g/ha alone was not effective in controlling *L. chinensis.* Abeysekera and Wickrama (2004), Jacob (2014) and Atheena (2016) also observed the inefficiency of bispyribac-sodium in controlling *L. chinensis*. On the other hand, it's combination with fenoxaprop-p-ethyl (at 25 + 60 g/ha) and cyhalofop-butyl (at 25 + 80 g/ha) resulted in a conspicuous reduction in *L. chinensis* population during all stages of observation. Wang *et al*. (2000) and Mahajan and Chauhan (2015) reported improved control of *L.*

chinensis with the tank mix of fenoxaprop-p-ethyl and bispyribac-sodium.

Stale seedbed *fb* glyphosate + oxyfluorfen (at 800 + 150 g/ha) *fb* cyhalofop-butyl + carfentrazone-ethyl (at 80 + 200 g/ha) was effective in controlling the germination and establishment of *L. chinensis* in the early stages of the crop, as indicated by the *L. chinensis* density at 15 and 30 DATA. A higher germination (95%) percentage immediately after maturity indicated the absence of dormancy in *L. chinensis* and reiterated the implication of stale seedbed strategies before crop establishment to deplete the soil seed bank (Chauhan and Johnson 2008). Application of cyhalofop-butyl at 80 g/ha alone and the tank mix combination of cyhalofop-butyl with carfentrazone-ethyl at 80 + 200 g/ha or bispyribac-sodium at 80 + 25 g/ha were effective in controlling *L. chinensis* and brought about considerable reduction (93-97%) in the count of *L. chinensis* in the early stages of the crop during both the years. Jacob (2014) reported cyhalofop-butyl as the next best herbicide to fenoxaprop-p-ethyl in controlling grasses including *L. chinensis*.

Considerable reduction (24-50%) in *L. chinensis* population was observed with the application of fenoxaprop-p-ethyl at 60 g/ha alone compared to its combined application with bispyribac-sodium at 25 g/ha during both the years. It was also observed that the tank mix combinations of cyhalofop-butyl with penoxsulam or carfentrazone-ethyl or bispyribac-sodium recorded highest *L. chinensis* count compared to the application of cyhalofop-butyl alone. Application of fenoxaprop-p-ethyl at 60 g/ha or cyhalofop-butyl at 80 g/ha alone resulted in 35-50% and 11-40% reduction in *L. chinensis* population, respectively compared to its tank mix combinations. This might be due to the antagonistic responses of the herbicides used for the combinations against the weed. Studies conducted by Bhullar *et al*. (2016) also observed antagonistic effect of bispyribac-sodium and fenoxaprop-p-ethyl mixture for the control of *L. chinensis* during 2012. However, the tank mix combination of fenoxaprop-p-ethyl + bispyribac-sodium (at 60 + 25 g/ha) was effective in managing the total weed population. Application of fenoxaprop-p-ethyl at 60 g/ha or cyhalofop-butyl at 80 g/ha was not able to control the complex spectrum of weed (**Table 2**) as indicated by the increased total population of weeds contributed by broad-leaf weeds and sedges in the plots treated with these herbicides alone (**Table 1**). Ready-mix combination of penoxsulam with cyhalofop-butyl at 150 g/ha was less effective in controlling the *L. chinensis* population in the field during both the years, compared to the application of fenoxaprop-p-ethyl at 60 g/ha alone.

Weed dry weight and weed control efficiency

Treatments had a significant effect on dry matter production of *L. chinensis* at 15, 30 and 45 DATA during 2018 and 2019 (**Table 3**). Weed dry

Table 1. Effect of treatments on *L. chinensis* density and total weed density

Treatment	*L. chinensis* density (no./m²)						Total weed density (no./m²)			
	15 DATA		30 DATA		45 DATA		15 DATA		45 DATA	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Cyhalofop-butyl (80 g/ha)	1.1	1.7	2.2	2.1	3.0	2.1	10.8	10.4	11.8	13.1
	(1.3)	(2.6)	(5.3)	(4.0)	(9.3)	(5.3)	(121.3)	(109.3)	(140.0)	(180.0)
Penoxsulam + cyhalofop-butyl (150 g/ha)	2.1	2.4	3.0	2.8	4.1	3.7	3.3	4.5	7.3	7.1
	(5.3)	(5.3)	(9.3)	(8.0)	(17.3)	(13.3)	(14.6)	(20.0)	(54.6)	(52.0)
Cyhalofop-butyl + carfentrazone-ethyl (80+200 g/ha)	0.7	1.3	2.0	2.1	3.4	2.3	5.8	5.8	8.8	8.0
	(0)	(1.3)	(4.0)	(4.0)	(12.0)	(5.3)	(34.6)	(33.3)	(90.6)	(68.0)
Bispyribac-sodium (25 g/ha)	6.5	6.0	8.9	7.6	9.0	8.0	7.1	6.6	9.9	9.4
	(44.0)	(36.0)	(80.0)	(58.6)	(81.3)	(64.0)	(53.3)	(44.0)	(98.6)	(90.6)
Bispyribac-sodium + cyhalofop-butyl (25+80 g/ha)	1.6	1.7	2.5	2.6	3.0	2.9	5.3	3.3	10.7	5.5
	(2.6)	(2.6)	(6.6)	(6.6)	(9.3)	(8.0)	(28.0)	(10.6)	(118.6)	(30.6)
Bispyribac-sodium + fenoxaprop-p-ethyl (25+60 g/ha)	0.7	0.7	2.0	1.6	2.5	2.4	1.1	1.7	4.5	3.2
	(0)	(0)	(4.0)	(2.6)	(6.6)	(5.3)	(1.3)	(2.6)	(21.3)	(10.6)
Fenoxaprop-p-ethyl (60 g/ha)	0.7	0.7	1.6	1.1	2.0	2.1	8.3	11.6	8.3	12.0
	(0)	(0)	(2.6)	(1.3)	(4.0)	(4.0)	(76.0)	(136.0)	(73.3)	(148.0)
Stale seedbed *fb* glyphosate + oxyfluorfen *fb* cyhalofop-butyl	0.7	0.7	2.0	2.1	3.0	2.3	0.7	0.7	12.9	8.4
+ carfentrazone-ethyl (800 + 150 *fb* 80 + 200 g/ha)	(0)	(0)	(4.0)	(4.0)	(9.3)	(5.3)	(0.0)	(0.0)	(168.0)	(72.0)
Hand weeding	0.7	0.7	1.1	1.7	3.0	2.9	2.5	2.9	6.5	3.9
	(0)	(0)	(1.3)	(2.6)	(9.3)	(8.0)	(6.6)	(8.0)	(44.0)	(16.0)
Unweeded control	8.0	8.8	10.1	10.9	10.9	9.3	17.0	14.3	12.8	14.2
	(64.0)	(78.6)	(104.0)	(119.0)	(120.0)	(88.0)	(292.0)	(206.6)	(165.3)	(208.0)
LSD (p=0.05)	14.99	5.05	2.77	3.82	2.76	8.83	3.03	0.56	3.12	2.90

DATA – Days after treatment application; *fb,* Followed by; BLW – Broad-leaf weeds; LSD: Least significant difference at the 5% level of significance; The figures in the parentheses are original values weight of *L. chinensis* was the highest in unweeded control during both the years at 15, 30 and 45 DATA and was statistically at par with bispyribac-sodium at 25 g/ha during both the years and resulted in the lowest weed control efficiency. The inefficiency of bispyribac-sodium at 25 g/ha in controlling *L. chinensis* population resulted in high dry matter production of *L. chinensis* in bispyribac-sodium treated plots and hence resulted in lower weed control efficiency.

Fenoxaprop-p-ethyl at 60 g/ha treated plots registered the lowest dry matter production of *L. chinensis* at all stages of observation during both the years, however, it was statistically comparable with all other treatments except unweeded control and bispyribac-sodium at 25 g/ha. The treatments fenoxaprop-p-ethyl at 60 g/ha, bispyribac-sodium + fenoxaprop-p-ethyl at 25 + 60 g/ha, stale seedbed *fb* glyphosate + oxyfluorfen + cyhalofop-butyl + carfentrazone-ethyl at 800 + 150 *fb* 80 + 200 g/ha were free of *L. chinensis* at the initial stages of crop growth during both the years.

Dry matter production of *L. chinensis* was higher in tank mix combination of bispyribac-sodium with fenoxaprop-p-ethyl (at 25 + 60 g/ha) or cyhalofop-butyl (at 25 + 80 g/ha) compared to the sole application of fenoxaprop-p-ethyl and cyhalofop-butyl at all stages of observations during both the years. The antagonistic response of the herbicides used in the combination resulted in the increased dry matter production of *L. chinensis.*

Ready-mix combination of penoxsulam + cyhalofop-butyl at 150 g/ha was very effective in managing the complex spectrum of weeds (**Table 4**) however, this treatment registered higher dry matter production (**Table 3**) and lower control efficiency of *L. chinensis* compared to other herbicidal treatments (**Table 5**). In the present location of the experiment, the soil texture was sandy clay loam which might be the reason for poor control of *L. chinensis*. This is consistent with the findings of Prakash *et al*. (2017) and Verma *et al*. (2017) where ready mix formulation of penoxsulam + cyhalofop-butyl recorded higher total weed dry weight in sandy loam soil. At 45 DATA,

Table 2. Effect of treatments on weed density at 45 DATA

Treatment	Weed density (no./m^2)					
	2018			2019		
	Grasses	BLW	Sedges	Grasses	BLW	Sedges
Cyhalofop-butyl (80 g/ha)	6.2(38.6)	8.2(68.0)	5.5(33.3)	4.4(20.0)	11.1(129.3)	5.1(30.6)
Penoxsulam + cyhalofop-butyl (150 g/ha)	5.4(29.3)	5.0(25.3)	0.7(0.0)	6.2(40.0)	3.5(12.0)	0.7(0.0)
Cyhalofop-butyl + carfentrazone-ethyl (80+200 g/ha)	6.2(42.6)	3.0(10.6)	5.1(37.3)	4.6(22.6)	6.1(42.6)	1.4(2.6)
Bispyribac-sodium (25 g/ha)	9.6(93.3)	2.2(5.3)	0.7(0.0)	9.4(90.6)	0.7(0.0)	0.7(0.0)
Bispyribac-sodium + cyhalofop-butyl (25+80 g/ha)	7.3(57.3)	6.3(40.0)	4.3(21.3)	4.8(24.0)	2.2(6.6)	0.7(0.0)
Bispyribac-sodium + fenoxaprop-p-ethyl (25+60 g/ha)	3.3(10.6)	3.1(10.6)	0.7(0.0)	3.2(10.6)	0.7(0.0)	0.7(0.0)
Fenoxaprop-p-ethyl (60 g/ha)	3.5(12.0)	6.8(53.3)	2.5(8.0)	3.8(14.6)	10.8(120.0)	3.5(13.3)
Stale seedbed *fb* glyphosate + oxyfluorfen *fb* cyhalofop-butyl + carfentrazone-ethyl (800 + 150 *fb* 80 + 200 g/ha)	3.9(20.0)	6.5(44.0)	10.2(104.0)	4.8(24.0)	6.2(40.0)	2.8(8.0)
Hand weeding	3.0(12.0)	5.6(32.0)	0.7(0.0)	3.0(9.3)	2.1(5.3)	1.1(1.3)
Unweeded control	12.1(148.0)	4.1(17.3)	0.7(0.0)	12.4(156.0)	6.7(52.0)	0.7(0.0)
LSD (p=0.05)	2.67	2.17	2.99	1.40	2.86	1.89

DATA – Days after treatment application; *fb,* Followed by; BLW – Broad-leaf weeds; LSD: Least significant difference at the 5% level of significance; The figures in the parentheses are original values

Table 3. Effect of treatments on dry weight of *L. chinensis*

Treatment	Dry weight of *L. chinensis* (kg/ha)					
	15 DATA		30 DATA		45 DATA	
	2018	2019	2018	2019	2018	2019
Cyhalofop-butyl (80 g/ha)	1.2(1.6)	1.3(1.9)	4.1(17.4)	3.8(13.9)	6.7(44.7)	6.8(43.9)
Penoxsulam + cyhalofop-butyl (150 g/ha)	2.2(6.6)	1.5(2.4)	4.9(24.3)	5.4(33.1)	9.4(88.4)	8.9(80.1)
Cyhalofop-butyl + carfentrazone-ethyl (80+200 g/ha)	0.7(0.0)	1.2(1.4)	4.4(26.0)	3.2(13.8)	6.6(61.2)	6.8(47.3)
Bispyribac-sodium (25 g/ha)	7.7(62.1)	5.8(47.2)	14.8(219.3)	12.4(170.7)	22.7(519.0)	21.0(446.2)
Bispyribac-sodium + cyhalofop-butyl (25+80 g/ha)	1.6(2.5)	1.6(2.4)	4.9(24.7)	4.3(18.5)	6.5(42.7)	6.9(48.8)
Bispyribac-sodium + fenoxaprop-p-ethyl (25+60 g/ha)	0.7(0.0)	0.7(0.0)	3.2(13.9)	2.5(7.9)	4.8(31.4)	5.9(36.4)
Fenoxaprop-p-ethyl (60 g/ha)	0.7(0.0)	0.7(0.0)	2.8(16.2)	1.7(4.4)	4.9(23.9)	5.4(30.1)
Stale seedbed *fb* glyphosate + oxyfluorfen *fb* cyhalofop-butyl + carfentrazone-ethyl (800 + 150 *fb* 80 + 200 g/ha)	0.7(0.0)	0.7(0.0)	3.2(14.0)	2.9(10.7)	5.5(42.2)	6.4(42.6)
Hand weeding	0.7(0.0)	0.7(0.0)	1.9(6.3)	2.2(9.2)	5.5(41.8)	6.2(39.4)
Unweeded control	8.5(74.0)	10.6(121.3)	15.5(240.7)	17.9(374.5)	28.7(826.1)	29.2(855.0)
LSD (p=0.05)	1.80	2.98	2.83	6.2	4.78	1.61

DATA – Days after treatment application; *fb,* Followed by; BLW – Broad-leaf weeds; LSD: Least significant difference at the 5% level of significance; The figures in the parentheses are original values the dry matter production of *L. chinensis* in unweeded control has increased to three-fold (826.13 kg/ha) compared to 30 DATA. Hand weeded treatment recorded statistically similar dry matter and control efficiency of *L. chinensis* with all the tested herbicides and herbicide combinations except with bispyribac-sodium at 25 g/ha. However, hand weeded treatment recorded 41.8 and 39.4 kg/ha of *L. chinensis* dry matter at 45 DATA might be due to the similar morphology of this weed with rice crop in the seedling stages resulting in the escape of some weeds from hand weeding.

Yield and yield attributes

Tank mix combination of bispyribac-sodium with fenoxaprop-p-ethyl (at 25 + 60 g/ha) or cyhalofop-butyl (at 25 + 80 g/ha) and ready mix combination of penoxsulam + cyhalofop-butyl at 150 g/ha produced a similar number of tillers/m^2, number of grains/panicle and percentage of filled grains compared to hand weeded treatment (weed free check) during the years 2018 and 2019 (**Table 6**). All the tested herbicides and the herbicide combinations applied for the management of weeds increased the grain yield compared to unweeded control during both the years and yield ranged from 2.13 to 4.93 t/ha during 2018 and from 2.01 to 5.47 t/ha during 2019. The better yield performance of herbicide application might be the result of increased resource utilization by the crop due to decreased dry matter accumulation by the weed under these treatments.

Season-long weed competition in unweeded control caused 56.77% reduction in the yield during the first season and 63.13% compared to the treatments with the highest grain yield (bispyribac-sodium + fenoxaprop-p-ethyl at 25 + 80 g/ha during 2018 and penoxsulam + cyhalofop-butyl at 150 g/ha during 2019).

In both the years, tank mix combination of bispyribac-sodium with fenoxaprop-p-ethyl at 25 + 60 g/ha (4.76 and 5.30 t/ha) and cyhalofop-butyl at 25 + 80 g/ha (4.37 and 5.14 t/ha) and ready-mix combination of penoxsulam + cyhalofop-butyl at 150 g/ha treated plots recorded statistically similar grain yield (4.55 and 5.36 t/ha) to the plots kept weed free throughout the season (4.93 and 5.47 t/ha).

Table 4. Effect of treatments on total weed dry weight

Treatment	Weed dry weight (kg/ha)					
	15 DATA		30 DATA		45 DATA	
	2018	2019	2018	2019	2018	2019
Cyhalofop-butyl (80 g/ha)	9.2(86.0)	7.7(60.4)	25.0(626.6)	24.5(604.8)	39.0(1524.3)	35.0(1241.7)
Penoxsulam + cyhalofop-butyl (150 g/ha)	4.9(23.9)	2.7(7.1)	8.4(73.0)	7.5(56.5)	16.7(287.2)	15.7(249.9)
Cyhalofop-butyl + carfentrazone-ethyl (80+200 g/ha)	8.5(72.8)	6.7(45.5)	20.6(425.5)	17.4(306.5	30.0(905.0)	27.1(740.3)
Bispyribac-sodium (25 g/ha)	8.5(73.8)	7.2(55.9)	17.8(320.7)	14.6(219.4)	26.5(704.4)	23.9(584.2)
Bispyribac-sodium + cyhalofop-butyl (25+80 g/ha)	5.2(29.6)	2.8(7.7)	9.2(85.0)	9.5(91.6)	16.8(283.9)	14.9(224.0)
Bispyribac-sodium + fenoxaprop-p-ethyl (25+60 g/ha)	3.9(18.8)	2.1(4.6)	5.4(29.7)	6.2(39.4)	14.7(222.4)	11.3(127.9)
Fenoxaprop-p-ethyl (60 g/ha)	8.8(78.8)	7.4(55.9)	24.7(612.7)	21.0(448.6)	37.5(1411.7)	33.6(1137.0)
Stale seedbed *fb* glyphosate + oxyfluorfen *fb* cyhalofop-butyl + carfentrazone-ethyl (800 + 150 *fb* 80 + 200 g/ha)	0.7(0.0)	0.7(0.0)	16.1(261.1)	15.4(238.0)	27.0(730.5)	26.0(684.2)
Hand weeding	4.0(16.4)	2.4(5.5)	5.3(28.6)	5.1(26.6)	10.8(117.5)	10.8(118.6)
Unweeded control	18.0(333.6)	19.3(374.8)	43.1(1867.1)	44.2(1978.2)	43.0(1850.9)	38.5(1492.2)
LSD (p=0.05)	1.80	2.98	2.83	6.26	4.78	1.61

DATA – Days after treatment application; *fb,* Followed by; BLW – Broad-leaf weeds; LSD: Least significant difference at the 5% level of significance; The figures in the parentheses are original values

Table 5. Effect of treatments on *L. chinensis* control efficiency, total weed control efficiency at 45 DATA and weed index

Treatment	*L. chinensis* CE (%)		Total WCE (%)		Weed index	
	2018	2019	2018	2019	2018	2019
Cyhalofop-butyl (80 g/ha)	94.5	94.4	17.6	20.2	33.6	60.3
Penoxsulam + cyhalofop-butyl (150 g/ha)	89.2	90.6	84.4	83.2	7.6	7.2
Cyhalofop + carfentrazone-ethyl (80 + 200 g/ha)	92.5	94.4	51.1	50.3	25.3	23.1
Bispyribac-sodium (25 g/ha)	37.0	47.8	61.9	60.8	23.5	23.3
Bispyribac-sodium + cyhalofop-butyl (25 + 80 g/ha)	94.8	94.2	84.6	84.9	11.3	8.9
Bispyribac-sodium + fenoxaprop-p-ethyl (25 + 60 g/ha)	96.1	95.7	87.9	91.4	6.3	3.0
Fenoxaprop-p-ethyl (60 g/ha)	97.1	96.4	23.7	23.7	34.9	43.0
Stale seedbed *fb* glyphosate + oxyfluorfen *fb* cyhalofop-butyl + carfentrazone-ethyl (800 + 150 *fb* 80 + 200 g/ha)	94.8	95.0	60.5	54.1	18.2	13.3
Hand weeding	94.93	95.3	93.6	92.0	0.00	0.00
Unweeded control	-	-	-	-	56.7	63.1

DATA: Days after treatment application; CE: Control efficiency; *fb:* Followed by

Table 6. Effect of treatments on yield attributes and grain yield

Treatment	No. of tillers/m^2		No. of panicles/m^2		No. of grains/panicle		Filled grains (%)		Grain yield (t/ha)	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Cyhalofop-butyl (80 g/ha)	249.3	265.3	224.0	210.6	114.0	139.0	52.8	60.1	3.26	2.17
Penoxsulam + cyhalofop-butyl (150 g/ha)	316.0	328.0	304.0	290.6	133.6	162.6	68.2	77.8	4.55	5.36
Cyhalofop + carfentrazone-ethyl (80+200 g/ha)	285.3	302.6	254.6	240.0	111.6	161.0	58.3	64.2	3.68	4.20
Bispyribac-sodium (25 g/ha)	314.6	321.3	264.0	258.6	120.6	167.6	61.0	69.4	3.76	4.19
Bispyribac-sodium + cyhalofop-butyl (25+80 g/ha)	336.0	330.6	272.0	276.0	131.6	170.0	63.0	72.6	4.37	5.14
Bispyribac-sodium + fenoxaprop-p-ethyl (25+60 g/ha)	318.6	336.0	321.3	304.0	132.6	176.0	71.6	76.1	4.76	5.30
Fenoxaprop-p-ethyl (60 g/ha)	289.3	270.6	213.3	228.0	114.0	151.3	57.9	65.0	3.20	3.12
Stale seedbed *fb* glyphosate + oxyfluorfen *fb* cyhalofop-butyl + carfentrazone-ethyl (800 + 150 *fb* 80 + 200 g/ha)	302.6	322.6	274.6	258.6	116.3	145.0	66.4	67.6	4.02	4.74
Hand weeding	313.3	330.6	304.0	288.0	133.3	170.3	61.6	69.2	4.93	5.47
Unweeded control	202.6	197.3	100.0	104.0	96.3	106.0	44.2	53.4	2.13	2.01
LSD (p=0.05)	23.5	24.6	58.4	53.4	17.9	22.4	13.0	12.4	0.88	1.02

fb: Followed by; LSD: Least significant difference at the 5% level of significance

Stale seedbed *fb* glyphosate + oxyfluorfen *fb* cyhalofop-butyl + carfentrazone-ethyl (at 800 + 150 *fb* 80 + 200 g/ha) and bispyribac-sodium at 25 g/ha alone produced statistically similar grain yield during 2019. Among the tank mix application of herbicides, the lowest grain yield was obtained in plots treated with cyhalofop-butyl + carfentrazone-ethyl at 80 + 200 g/ha (3.68 and 4.20 t/ha). Cyhalofop-butyl at 80 g/ha (3.26 and 2.17 t/ha) and fenoxaprop-p-ethyl at 60 g/ha (3.20 and 3.12 t/ha) treated plots produced significantly inferior grain yield during both the years and was comparable with the weedy check (2.13 and 2.01 t/ha) during 2019. This might be due to the inefficiency of cyhalofop-butyl and fenoxaprop-p-ethyl to control broad-leaf weeds and sedges even though they are excellent in controlling grass weeds.

Conclusion

It was concluded that fenoxaprop-p-ethyl at 60 g/ha and cyhalofop-butyl at 80 g/ha at 15-18 DAS were the most effective herbicide against *L. chinensis*. In places where *L. chinensis* is not a problem, broad-spectrum herbicide bispyribac-sodium alone at 25 g/ha can be recommended. Fenoxaprop-p-ethyl and cyhalofop-butyl were ineffective in managing broad-leaf weeds and sedges resulting in high weed dry matter production. Hence, these herbicides need to be used in combinations with bispyribac-sodium for broad-spectrum weed control.

REFERENCES

Abeysekera ASK and Wickrama UB 2004. Control of *Leptochloa chinensis* (L) Nees in wet-seeded rice fields in Sri Lanka, pp 215-217 In: *Rice is Life: Scientific Perspectives for the 21st Century. Proceedings of World Rice Research Conference*, 4-7 November 2004, Japan. International Rice Research Institute, Philippines.

Atheena A. 2016. *Tank-mix Application of Cyhalofop-butyl with Selected Herbicides for Weed Control in Wet Seeded Rice*. M.Sc. (Ag) Thesis, Department of Agronomy, Kerala Agricultural University, Thrissur. 101p.

Bhullar MS, Kumar S, Kaur S, Kaur T, Singh J, Yadav R, Chauhan BS and Gill G. 2016. Management of complex weed flora in dry-seeded rice. *Crop Protection* **83**: 20–26.

CABI. 2019. Invasive Species Compendium- *Leptochloa chinensis* (Chinese sprangletop). https://www.cabi.org/isc/datasheet/30207 (accessed 18 May 2020).

Chauhan BS and Johnson DE. 2008. Germination ecology of Chinese sprangletop (*Leptochloa chinensis*) in the Philippines. *Weed Science* **56**(6): 820–825.

Duary B. 2008. Recent advances in herbicide resistance in weeds and its management. *Indian Journal of Weed Science* **24**: 124–135.

Galinato MI, Moody K, and Piggin CM. 1999. *Upland Rice Weeds of South and South-East Asia*. International Rice Research Institute, Philippines. 156 p.

Jacob G, Menon MV, and Abraham CT. 2017. Herbicidal management of Chinese sprangletop (*L. chinensis*) in direct-seeded rice. *Indian Journal of Weed Science* **49**(2): 176–178.

KAU (Kerala Agricultural University). 2016. *Package of Practices Recommendations: Crops (15th Ed.)*. Kerala Agricultural University, Thrissur. 392p.

Mahajan G and Chauhan BS. 2015. Weed control in dry direct-seeded rice using tank mixtures of herbicides in South Asia. *Crop Protection* **72**: 90–96.

Marambe B. 2002. Emerging weed problems in wet-seeded rice due to herbicide use in Sri Lanka. In: *Abstracts International Rice Congress*, Beijing, China. 430p.

Prakash J, Singh R, Yadav RS, Vivek, Yadav RB, Dhyani BP and Sengar RS. 2017. Effect of different herbicide and their combination on weed dynamics in transplanted rice. *Research Journal of Chemical and Environmental Sciences* **5**(4): 71–75.

Verma DK, Pandey A, Giri SP, Verma S, Singh J, Singh AK and Kumar A. 2017. Efficacy of different herbicidal formulation and its effect on soil microflora in transplanted rice of eastern Uttar Pradesh. *Journal of Pharmacognosy and Phytochemistry* 522–525.

Wang Q, Zhao XP, Wu CX, Dai F, Wu LQ, Xu H, Zhang RJ, Cai GL and Weng X.Z. 2000. Application techniques of bispyribac-sodium for controlling weeds in direct-seeded rice fields. *Acta Agriculture Zhejiangensis* **12**: 338–344.

Indian Journal of Weed Science **52**(3): 217–221, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Crop establishment and weed management effect on weed parameters and rice yield under temperate zone of Kashmir

Aijaz Nazir*, M. Anwar Bhat, Tauseef A. Bhat, Zahida Rashid, Rehana Mohi-ud-din, Suhail Fayaz and Sheraz Ahmad Wani

Sher-e-Kashmir University of Agricultural sciences and Technology of Kashmir, Sopore, Jammu & Kashmir 193201, India

**Email: magreyaijaz357@gmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00041.6

Type of article: Research article

Received : 26 June 2020
Revised : 27 August 2020
Accepted : 30 August 2020

Key words

Crop establishment methods

Herbicides

Rice

System of rice intensification

Weed management

ABSTRACT

A field experiment was conducted during *Kharif* (rainy) seasons of 2017 and 2018 at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Jammu and Kashmir. The treatments comprised of three crop establishment methods, *viz.* transplanting, direct seeding (DSR), System of Rice Intensification (SRI) in main plots and seven weed management practices, *viz.* butachlor (1500 g/ha), penoxsulam (22.5g/ha), pyrazosulfuron-ethyl + pretilachlor (15 and 600g/ha), bensulfuron methyl + pretilachlor (60 and 600 g/ha), twice conoweeding/hand weeding, weed free and weedy check in sub-plots replicated thrice in a split plot design. The results revealed that significantly lowest weed density and weed dry weight were recorded with transplanted method as compared to SRI and DSR. Application of penoxsulam 22.5 g/ha recorded significantly the lowest weed population and weed dry matter depicting higher weed control efficiency. SRI had resulted in significantly higher yields over DSR and transplanted rice. Penoxsulam (22.5 g/ha) produced significantly higher grain and straw yields. SRI proved to be better method of crop establishment than transplanting and DSR whereas, application of penoxsulam 22.5 g/ha proved superior to other herbicide treatments used.

INTRODUCTION

Rice is the primary food source for more than half of the world's population and is cultivated globally over an area of about 158.8 million hectares with a production of 751.9 million tonnes annually (FAO, 2017). India, the largest rice growing country of the world after China, contributes 21.5% to global rice production. Transplanting is the most dominant method of rice establishment in Kashmir valley, however the shortage of labour and water are pressing farmers to explore the alternatives of conventional transplanting. The area under transplanted rice in world is decreasing due to scarcity of water and labour. So, there is need to search for alternate crop establishment methods to increase the productivity of rice (Farooq *et al.* 2011). Direct seeding reduces labour requirement, shortens the crop duration by 7-10 days and can produce as much grain yield as that of transplanted crop. The system of rice intensification (SRI) was recently promoted as an alternative technology and resource management strategy for rice cultivation that offers the opportunity to boost rice yields with less external inputs. The SRI consists of a set of management practices that were mainly developed in areas with scarcity of water and labour.

Weed management is major prerequisite for improved rice productivity in all the rice establishment methods. Although a number of pre-emergence herbicides provide good control of grassy weeds but due to continuous use of such herbicides, a shift in weed flora and evolution of herbicide resistant weeds has been observed. Crop selective, new generation low dose micro-herbicides like sulfonylureas (bensulfuron-methyl, metsulfuron-methyl, chlorimuron-ethyl, pyrazosulfuron-ethyl, bispyribac-sodium *etc.*) are gaining popularity among farmers for their promising role in weed control. Penoxsulam (acetolactate synthase (ALS) inhibitor) is also a new promising herbicide for effective control of annual grasses, sedges and broad-leaf weeds whereas pyrazosulfuron-ethyl was found effective for complex weed flora in rice (Maiti *et al.* 2003). The present study was planned to evaluate the performance of low dose herbicides as influenced by rice establishment methods.

MATERIALS AND METHODS

The field experiment was conducted at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Faculty of Agriculture, Wadura, Jammu and Kashmir during *Kharif* (rainy) seasons 2017 and 2018. The experimental site falls in mid altitude temperate zone with an average annual precipitation of 812 mm. The total rainfall received during the experimentation period (May to September) was 339.4 and 352.5 mm during *Kharif* 2017 and 2018, respectively. The soil of experimental field was silty clay loam in texture, neutral in reaction (pH 6.9), medium in available N, P and K with medium organic carbon content. The treatments consisted of three crop establishment methods, *viz*. transplanting, direct seeding and SRI in main plots and seven weed management practices, *viz*. butachlor (1500 g/ha), penoxsulam (22.5 g/ha), pyrazosulfuron-ethyl + pretilachlor (15 and 600 g/ha), bensulfuron-methyl + pretilachlor (60 and 600 g/ha), twice conoweeding/hand weeding, weed free and weedy check in sub plots. The treatments were replicated thrice in a split plot design. For SRI method, 12-day old seedlings of variety '*Shalimar Rice 4*' were transplanted in last week of May at a spacing of 25 x 25 cm. For direct-seeded rice (DSR), pre-germinated seeds were sown in rows 20 cm apart in well prepared plots on 17th May while for transplanting, nursery sowing was done with same pre-germinated seeds on the same date and then 25 day old seedlings were transplanted at a spacing of 20 x 10 cm. Well decomposed farm yard manure 10 t/ha was incorporated in treatment plots uniformly during land preparation. The entire quantity of phosphorus (60 kg/ha) and potassium (30 kg/ha) and half of nitrogen (60 kg/ha) was applied as basal at the time of transplanting while remaining N was applied in two equal splits at active tillering (30 kg/ha) and panicle initiation stage (30 kg/ha). Under SRI method all the principles were followed. Water management in both SRI and DSR was done in such a way that there was no continuously standing water during the vegetative growth phase while thin film of water was maintained during flowering to soft dough stage. Under transplanting method, plots were flooded with water. Herbicides in liquid formulation were applied with knapsack sprayer fitted with flat-fan nozzle using 300 liters of water per ha whereas the granular herbicides were mixed with sand and applied uniformly across the plot. Weed density (no. of weeds/m^2) was recorded at 45 days after transplanting (DAT) using a quadrate 0.25 m^2 (0.5 x 0.5 m). The weeds falling in the quadrate randomly at two points from each plot in all replications were identified and grouped. The samples collected for the weed density were sun dried first and then dried in oven to determine the dry weight of weeds. Weed control efficiency (WCE) of different treatments was determined by using the following formula:

$$\text{WCE (\%)} = \frac{Wc - Wt}{Wc} \times 100$$

Where, Wc = weed dry weightin weedy (control) plot and

Wt = weed dry weight in herbicide treated plot.

Weed index (WI) of different treatments was determined using the following formula:

$$\text{WI} = \frac{\text{YWF} - \text{YT}}{\text{YWF}} \times 100$$

Where, YWF = crop yield in weed free plot and

YT= crop yield in treated plot

RESULTS AND DISCUSSION

Effect on weeds

The prominent grassy weeds were *Echinochloa crusgalli, Echinochloa colona* and *Cynodon dactylon*. Broad-leaved weeds were *Ammania baccifera, Marsilea qudrofolia, Monochoria vaginalis* and *Potamogeton distinctus* while the prominent sedges included *Cyperus iria, Cyperus defformis* and *Fimbristylis.*

Significantly lower density was recorded with transplanted method at 30, 45 and 60 DAT/DAS and at harvest over SRI and DSR (**Table 1**). The superiority exhibited by transplanted rice in reducing weed densities over SRI and direct-seeded rice at 60 DAT/DAS were 11.03 and 41.09% during 2017 and the corresponding figures were 11.87 and 42.74%, respectively during 2018. Weed dry matter was significantly reduced under transplanted rice over SRI and DSR, SRI in turn was significantly superior to direct-seeded rice at all growth stages of crop. Superiority exhibited by transplanted rice in reducing the weed dry matter over SRI and DSR at 60 DAT/DAS was 8.55 and 42.11% during 2017 and 8.96 and 43.34% during 2018, respectively (**Table 2**). Continuous submergence of the transplanted crop effectively suppressed the weed population and weed seed germination under transplanted rice. The results was in agreement with the findings of Subramanian *et al*. (2007). SRI recorded significantly a lower weed index of 3.55 during both the years while as transplanted and DSR recorded a weed index of 3.67 and 3.63 and 3.92 and 3.89 during 2017 and 2018, respectively (**Table 3**). Continuous submergence of the transplanted crop effectively suppressed the weed population and weed seed germination under transplanted rice. The results were in agreement with the findings of Subramanian *et al*. (2007); Bhat *et al*. (2011) and Saha and Bharti (2010).

Effective weed control was observed with the application of penoxsulam 22.5 g/ha during both the years. The superiority exhibited by penoxsulam 22.5 g/ha at 60 DAT/DAS over weedy check and butachlor (1500 g/ha) was 54.31 and 32.68% during 2017, and 56.0 and 34.48% for 2018, respectively (**Table 1**). Application of penoxsulam 22.5 g/ha significantly reduced the weed dry matter over weedy check at 30, 45, 60 DAT/DAS and at harvest. Reduction in weed dry matter at 60 DAT/DAS by penoxsulam 22.5 g/ha over weedy check and butachlor 1500 g/ha was 50.22 and 24.32 during 2017 and the corresponding figures for 2018 were 51.44 and 25.44, respectively (**Table 2**). This might be due to the fact that herbicides not only exhibited significantly lesser toxicity to rice seedling but controlled the weeds very efficiently. This has established that penoxsulam is an effective post-emergence herbicide against a wider weed flora and selectivity to rice crop as well. Penoxsulam is a member of the triazolopyrimidine sulphonamide chemical family with ALS (acetolactate synthase) inhibition as its mode of action. It has a

Table 1. Effect of different crop establishment methods and weed management practices on weed density (no./m^2)

Treatment	30 DAT/DAS		45 DAT/DAS		60 DAT/DAS		Harvest	
	2017	2018	2017	2018	2017	2018	2017	2018
Crop establishment method								
Transplanting	2.78(9.1)	2.56(8.1)	3.33(13.4)	3.18(12.5)	3.87(17.6)	3.71(16.4)	3.12(11.9)	2.90(10.7)
Direct-seeding	5.01(28.5)	4.91(27.4)	5.6(36.5)	5.52(35.5)	6.57(50.0)	6.48(48.8)	6.02(41.9)	5.93(40.7)
System of rice intensification (SRI)	2.99(11.0)	2.79(9.9)	3.68(16.5)	3.54(15.6)	4.35(22.5)	4.21(21.3)	3.73(16.8)	3.56(15.6)
LSD(p=0.05)	0.03	0.04	0.03	0.03	0.04	0.06	0.09	0.08
Weed management practice								
Butachlor (1500 g/ha)	5.16(26.9)	5.04(25.7)	5.67(33.1)	5.54(31.7)	6.21(39.3)	6.09(37.9)	5.56(31.1)	5.45(30.0)
Penoxsulam (22.5 g/ha)	2.80(8.0)	2.53(7.2)	3.47(13.0)	3.22(11.6)	4.18(18.4)	3.99(17.0)	3.35(11.8)	3.16(10.7)
Pyrazosulfuron-ethyl + pretilachlor (15 and 600 g/ha)	2.89(8.9)	2.63(7.7)	3.71(15.1)	3.48(13.7)	4.52(21.3)	4.35(19.9)	3.58(13.2)	3.41(12.1)
Bensulfuron-methyl + pretilachlor (60 and 600 g/ha)	3.04(9.8)	2.80(8.6)	3.83(16.0)	3.61(14.6)	4.62(22.2)	4.45(20.8)	3.7(14.0)	3.54(12.9)
Twice cono weeding/ hand weeding (15 and 30 DAS/DAT)	3.35(11.7)	3.14(10.5)	4.08(17.9)	3.88(16.5)	4.82(24.2)	4.66(22.8)	3.95(16.0)	3.80(14.9)
Weed free	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)
Weedy check	6.89(47.8)	6.81(46.6)	8.26(69.4)	8.17(68.0)	9.15(85.0)	9.07(83.6)	8.27(68.9)	8.20(67.8)
LSD(p=0.05)	0.09	0.08	0.08	0.09	0.10	0.15	0.18	0.20

DAS/DAT: days after transplanting sowing; Figures in parentheses are original values; Data subjected to $(\sqrt{x+1})$ transformation

Table 2. Effect of different crop establishment methods and weed management practices on dry weed biomass (g/m^2)

Treatment	30 DAT/DAS		45 DAT/DAS		60 DAT/DAS		Harvest	
	2017	2018	2017	2018	2017	2018	2017	2018
Crop establishment method								
Transplanting	3.76(17.7)	3.57(16.4)	4.44(23.2)	4.28(21.9)	4.92(28.0)	4.77(26.5)	4.33(21.8)	4.12(20.0)
Direct-seeding	6.33(51.2)	6.23(49.9)	7.43(67.0)	7.35(65.6)	8.5(85.5)	8.42(84.0)	7.61(69.4)	7.50(67.6)
System of rice intensification (SRI)	4.34(23.4)	4.19(22.1)	4.94(29.0)	4.80(27.6)	5.38(33.8)	5.24(32.3)	4.77(26.8)	4.58(25.0)
LSD(p=0.05)	0.05	0.05	0.04	0.05	0.04	0.04	0.04	0.04
Weed management practice								
Butachlor (1500 g/ha)	5.87(35.3)	5.73(33.8)	6.65(45.8)	6.53(44.2)	7.36(56.8)	7.23(55.0)	6.69(46.7)	6.52(44.6)
Penoxsulam (22.5 g/ha)	3.38(11.6)	3.12(10.1)	4.61(22.1)	4.42(20.5)	5.57(33.0)	5.39(31.2)	4.82(24.5)	4.57(22.4)
Pyrazosulfuron-ethyl + pretilachlor (15 and 600 g/ha)	3.81(14.7)	3.59(13.2)	4.94(25.2)	4.76(23.6)	5.85(36.2)	5.68(34.4)	5.04(26.8)	4.81(24.7)
Bensulfuron-methyl + pretilachlor (60 and 600 g/ha)	4.33(18.8)	4.14(17.3)	5.35(29.3)	5.19(27.7)	6.20(40.2)	6.04(38.4)	5.24(28.7)	5.02(26.6)
Twice cono weeding/ hand weeding (15 and 30 DAS/DAT)	5.03(25.2)	4.87(23.7)	5.93(35.7)	5.79(34.1)	6.72(46.6)	6.57(44.8)	5.75(34.2)	5.56(32.1)
Weed free	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)
Weedy check	10.27(110)	10.19(108)	10.74(120)	10.66(118)	11.19(131)	11.10(129)	10.45(114)	10.34(112)
LSD(p=0.05)	0.11	0.11	0.098	0.10	0.09	0.09	0.10	0.10

DAS/DAT: days after transplanting sowing; Figures in parentheses are original values; Data subjected to $(\sqrt{x+1})$ transformation favourable toxicological and environmental profile. The results were in conformity with Bhat *et al.* (2011). At harvest penoxsulam 22.5 g/ha recorded weed control efficiency of 80.15 during 2017 and 82.01% during 2018 (**Table 3**). Reduction in weed biomass due to effective weed control measures resulted in higher weed control efficiency.

Among the weed management practices, penoxsulam 22.5 g/ha recorded minimum weed index of 2.09 and 2.08 during 2017 and 2018, respectively which was significantly superior to all other weed control treatments (**Table 3**). The data further revealed that the losses in grain yield of rice due to weeds were 49.94 and 42.22%. This might be due to lower weed densities that resulted in increased uptake of nutrients and thus increased grain yield (Bhat *et al.* 2011).

Effect on yield

Grain and straw yields of rice differed significantly due to various treatments during both the years of experimentation. SRI recorded significantly higher grain yield (7.92 and 8.17 t/ha), followed by normal transplanting (7.09 and 7.17 t/ha) whereas the lowest grain yield of 6.01 and 6.24 t/ha was observed in DSR (**Table 3**). The crop established by SRI method provided a yield advantage of 24.11 and10.47% during 2017 and 23.62 and 12.23% during 2018, over DSR and transplanting. SRI also recorded significantly higher straw yield than direct-seeded rice and transplanting. The higher grain and straw yield realized with SRI was probably due to transplanting of seedlings at younger age which preserves a potential for more tillering and rooting. Further, wider spacing in square pattern (25 x 25 cm) provided more room for both canopy and root growth and for subsequent grain filling. The increase in the grain yield under SRI method was attributed to larger root volume, profuse and strong tillers with longer panicles, more and well filled spikelets with higher grain weight. Comparable yields in rice through different systems of crop establishment with that of transplanting has been reported by Mahajan *et al.* (2012).

Among the weed control treatments, penoxsulam 22.5 g/ha provided significantly higher grain (8.19 and 8.28 t/ha) and straw (10.13 and 10.44 t/ha) yield over weedy check and other weed control treatments (**Table 3**). Penoxsulam 22.5 g/ha realized 26.25 and 22.34%, 7.32 and 6.15%, 11.23 and 10.02%, 13.79 and 13.76 % and 49.93 and 46.98% more grain yield as compared to butachlor (1500 g/ha), pyrazosulfuron-ethyl + pretilachlor (15 and 600 g/ha) bensulfuron-methyl + pretilachlor (60 and 600 g/ha), twice conoweeding/hand weeding and weedy check during 2017 and 2018, respectively. This could be possibly due to reduction in weed growth with the herbicide application which allowed the crop to get adequate nutrient supply resulting in higher leaf-area index and thus more production and assimilation of photosynthates contributing to higher grain and straw yield (Shan *et al.* 2012).

Among the different crop establishment methods and weed management practices, weed density and weed dry matter showed significantly negative correlation with grain yield. The regression value for grain yield with weed density (0.856 and 0.859) and weed dry matter (0.758 and 0.761), was significant during 2017 and 2018, respectively. The variations in weed density and weed dry matter could be explained to the extent of 85.6 (**Figure 1**) and 85.9% (**Figure 2**) and 75.8 (**Figure 3**) and 76.1% (**Figure 4**) during 2017 and 2018, respectively.

Table 3. Effect of different crop establishment methods and weed management practices on yield (t/ha) of rice

Treatment	Grain yield (t/ha)		Straw yield (t/ha)		Biological yield (t/ha)		Weed control efficiency (%)		Weed index (%)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Crop establishment method										
Transplanting	7.09	7.17	8.88	9.21	15.97	16.38	67.02	68.42	16.50	16.15
Direct-seeding	6.01	6.24	8.00	8.32	14.01	14.56	64.29	64.83	18.40	18.09
System of rice intensification (SRI)	7.92	8.17	9.60	10.17	17.52	18.34	67.77	69.47	14.89	14.82
LSD(p=0.05)	0.75	0.84	0.79	0.87	1.02	1.06	0.06	0.08	0.12	0.15
Weed management practice										
Butachlor (1500 g/ha)	6.04	6.43	8.23	8.67	14.27	15.10	59.84	61.21	29.64	29.19
Penoxsulam (22.5 g/ha)	8.19	8.28	10.13	10.44	18.32	18.71	80.15	82.01	3.55	3.51
Pyrazosulfuron-ethyl + pretilachlor (15 and 600 g/ha)	7.59	7.77	9.31	9.51	16.90	17.29	78.10	79.95	7.20	7.10
Bensulfuron-methyl + pretilachlor (60 and 600 g/ha)	7.27	7.45	9.03	9.37	16.30	16.83	76.02	77.81	11.10	10.93
Twice cono weeding/ hand weeding (15 and 30 DAS/DAT)	7.06	7.14	8.72	8.96	15.78	16.11	70.42	72.04	14.73	14.53
Weed free	9.00	9.29	10.75	11.19	19.74	20.47	100	100	0.00	0.00
Weedy check	4.10	4.39	6.06	6.50	10.15	10.88	0.00	0.00	49.94	42.22
LSD(p=0.05)	0.72	0.84	0.69	0.61	0.78	0.70	0.15	0.21	0.30	0.29

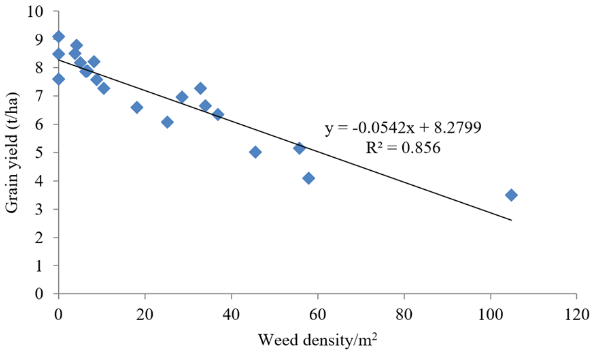

Figure 1. Linear regression line between weed density and grain yield among different crop establishment methods and weed management practices (2017)

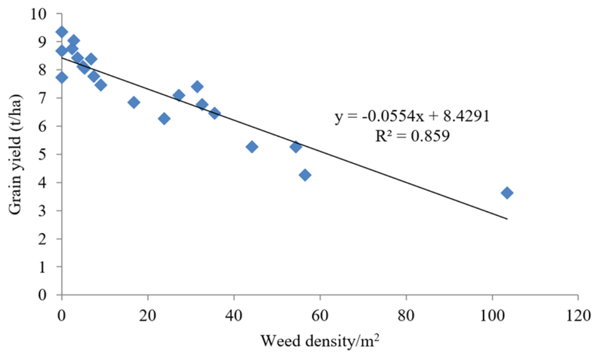

Figure 2. Linear regression line between weed density and grain yield among different crop establishment methods and weed management practices (2018)

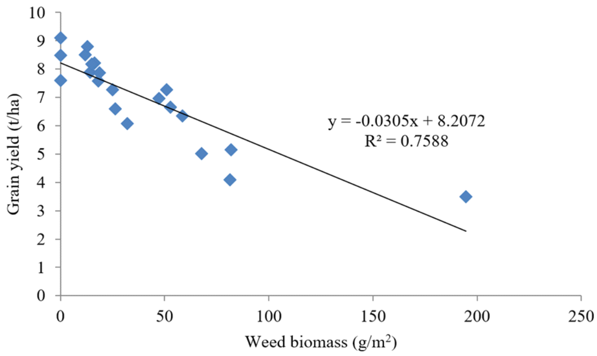

Figure 3. Linear regression line between weed biomass and grain yield among different crop establishment methods and weed management practices (2017)

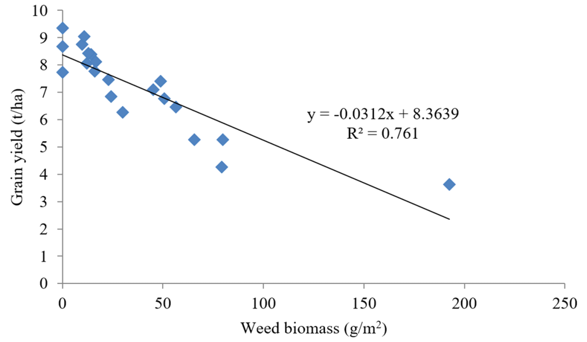

Figure 4. Linear regression line between weed biomass and grain yield among different crop establishment methods and weed management practices (2018)

Conclusion

SRI proved to be better method of crop establishment than transplanting and direct seeding whereas among the different herbicide treatments, penoxsulam was found superior in terms of grain yield and provided effective control of complex weed flora. Therefore, it was concluded that for enhancing the rice yield and for managing the weeds effectively, SRI with application of penoxsulam 22.5 g/ha was found effective to boost productivity of rice in Kashmir valley.

REFERENCES

Bhat MA, Hussain A, Ganai MA and Mushki GM. 2011. Effect of herbicides used alone and in combination on weeds and transplanted rice under temperate conditions of Kashmir. *Applied Biological Research* **13**: 75–78.

FAO. 2017. Food and Agriculture Organization of the United Nations, *Rice Monitor Vol. XX* issue no. 1, April, 2017.

Farooq M, Kadambot HM, Siddique H, Rehman TA and Dong-JinLee AW. 2011. Rice direct seeding: Experiences, challenges and opportunites- a review. *Soil and Tillage Research* **111**: 87–98.

Mahajan G, Chauhan BS and Gill MS. 2012. Optimal nitrogen fertilization timing and rate in dry-direct seeded rice in north-west India. *Agronomy Journal* **103**(6): 1676–1682.

Maiti S, Haldar P and Banerjee H. 2003. Management of weeds in boro rice with pyrazosulfuron-ethyl (PSE) under Gangetic Alluvial conditions of West Bengal. pp .76. In: *Proceedings of Biennial Conference*, Pantnagar. 12-14 March. Indian Society of Weed Science.

Saha A and Bharti V. 2010. Effect of different crop establishment methods on growth, yield and economics of rice (*Oryza sativa* L.). *Environment and Ecology* **28**(1): 519–522.

Shan FA, Bhat MA, Ganai MA, Hussain A and Bhat TA. 2012. Effect of crop establishment and weed control practices on the performance of rice (*Oryza sativa* L.). *Applied Biological Research* **14**(1): 79–85.

Subramanian E, Ramachandra BSNM and Balasubramanian R. 2007. Studies on the effect of weed management practices on weed control in drum seeded wet rice. *Indian Journal of Weed Science* **37**(3&4): 201–203.

Indian Journal of Weed Science **52**(3): 222–226, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Indian Journal of Weed Science

Efficacy of herbicides in managing weeds in direct-seeded rice

R.K. Satyaraj Guru*, Sanjay K. Dwivedi, S.N. Khajanji and S.K. Jha

Department of Agronomy, Indira Gandhi Krishi Vishwavidyalaya, Raipur Chhattisgarh 492 012, India

**Email: rksatyaraj34@gmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00042.8

Type of article: Research article

Received : 8 June 2020
Revised : 1 September 2020
Accepted : 4 September 2020

Key words

Direct-seeded rice

Post–emergence herbicide

Weed control efficiency

ABSTRACT

A field experiment was conducted during *Kharif* 2017 and 2018 at I.G.K.V, Raipur, Chhattisgarh to study the effect of existing herbicides in managing weeds in direct-seeded rice (*Oryza sativa* L.) and to assess their residual effect on succeeding crops. Application of bispyribac-sodium 2% (BS) + 2,4-D sodium salt 54.3% SP (DSS) with adjuvant (WA) (30.0 + 814.5 g/ha), BS + 2,4-DSS (WA) (25.0 + 678.75 g/ha), BS+ 2,4-DSS (30.0 + 814.5 g/ha) and BS + 2,4-DSS (WA) (20.0 + 543.0 g/ha) was at par to weed free in terms of grain yield. BS + 2,4- DSS (WA) (30.0 + 814.5 g/ha) controlled the weeds more effectively throughout the crop growth period and recorded higher weed control efficiency (97.5% at 30 DAS and 92.4% at 60 DAS), herbicide efficiency index (47.1 and 13.2), reduction of weed density (88.1 and 80.6%) and weed biomass (97.5 and 92.4%) and lower weed persistence index (0.2 and 0.4) during both the years. The phytotoxicity effect was observed with higher doses of BS + 2,4-DSS, alone and with adjuvant at 25.0 + 678.8 g/ha and 30.0 + 814.5 g/ha, however it was recovered quickly. There was no phytotoxicity and carryover effect of these herbicides tested on chickpea + linseed intercrop, grown as succeeding crop. Application of BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha) recorded highest net returns (₹ 65444 and 76762/ha) and B:C ratio (2.2 and 2.6) during 2017 and 2018, respectively.

INTRODUCTION

Rice is the source for 35-80% of total calorie intake of Asian population (Rahman and Masood 2012). Puddling and transplanting operations in conventional rice production system consume a significant quantity of water, creates a hard pan below the plough layer, reduces soil permeability, and deteriorates soil quality for the subsequent upland crops (Hossain *et al.* 2016). However direct-seeded rice (DSR) requires 35-57% less water and 67% less labour over transplanting rice (Chauhan 2012). Nevertheless, weeds are a major biological constraint in DSR, mainly due to the absence of impounding of water at crop emergence, hence weed management are crucial for increasing the productivity of DSR (Rao *et al.* 2007, Chauhan *et al.* 2012).

The extent of yield reduction of rice due to weeds has been estimated up to 95% in India (Pathak *et al.* 2011). The chemical method of weed control is becoming more popular and is the best alternative to hand weeding as hand weeding needs high labour involvement (190 man-days/ha), is tedious, time-consuming and impractical under adverse weather conditions (Rao *et al.* 2017). Use of herbicide mixtures would be more acceptable option as the operation would be completed in a single application and would save time (Menon 2019, Yadav *et al.* 2018) as well as it overcome the problem of herbicide resistance and the shift in weed flora (Damalas *et al.* 2005). It also reduces the usage rate, herbicide injury to crops and broadens the spectrum of weed control in a single application and reduces the cost of application (Afrin *et al.* 2015).

MATERIALS AND METHODS

The field experiment was conducted during *Kharif* 2017 and 2018 at the I.G.K.V, Raipur ($21^0 23'$ N, $81^0 71'$ E and 290 m above mean sea level), Chhattisgarh to study the effect of herbicides in managing weeds in direct-seeded rice and to assess their residual effect on succeeding chickpea + linseed crops. The soil was neutral in reaction (pH 6.5), low in available nitrogen, medium in phosphorus and high in potassium.

Eleven treatments *viz.* bispyribac-sodium 2% (BS) + 2,4-D-sodium salt 54.3% SP (DSS) (20.0 + 543.0 g/ha), BS+ 2,4-DSS (25.0 + 678.75 g/ha), BS + 2,4- DSS (30.0 + 814.5 g/ha), BS+ 2,4-DSS with adjuvant (WA) (20.0 + 543.0 g/ha), BS + 2,4-DSS (WA) (25.0 + 678.75 g/ha), BS + 2,4-DSS (WA) (30.0

+ 814.5 g/ha), bispyribac-sodium 10% SC 20 g/ha, 2,4-D ethyl ester 38% EC (34% W/W) (EE) (850 g/ha), penoxsulam 21.7% SC (22.5 g/ha), weed free (20 and 40 DAS) and weedy check were laid out in a randomized block design with three replications. Pre-germinated seeds of medium duration rice variety '*Indira Rajeshwari (IGKV R 1)*' were line sown on non-puddled levelled field on 20th and 30thJune of 2017 and 2018, respectively with a seed rate of 80 kg/ha.

The crop was fertilized with 100:60:40 N:P:K kg/ha during both the years, and 50% nitrogen, entire dose of phosphorous and potassium were applied as basal. The remaining 50% of the nitrogen was top dressed at two equal splits at tillering and panicle initiation stages. The study area receives rainfall of 716.0 mm in 2017 and 973.6 mm in 2018 during rice season, with a temperature variation of 24.9 to 32.2^{o}C in 2017 and 24.3 to 31.3^{o}C in 2018. The herbicides were sprayed at 2-3 leaf stage of weeds by knapsack sprayer with spray volume of 500 L/ha. All herbicide treatments were applied at 18 days after seeding (DAS). The data on weed density and weed biomass (at 30 and 60 DAS) were recorded with the help of quadrat (0.5 x 0.5 m). Phytotoxic effect of herbicides on rice was evaluated by observing for chlorosis, vein clearing, necrosis, wilting, scorching, epinasty and hyponasty of leaf at 1, 3, 5, 7 and 10 days after application (DAA) of herbicides. The observation on the level of phytotoxicity through visual assessment of crop response was rated in the scale of 1-10. Data on yield attributes like number of effective tillers, number of grains per panicle, test weight and grain yield were recorded. The weed control efficiency (at 30 and 60 DAS) was worked out on the basis of weed biomass. The herbicide efficiency index (HEI) was calculated as suggested by Krishnamurthy *et al.* (1975).

$$HEI = \frac{\frac{(Yt-Yc)}{Yt}}{\frac{WDMt}{WDMc}}$$

Where, Yt = Crop yield from the treated plot

Yc = Crop yield from the weedy check

WDMt = Weed dry weight in the treated plot

WDMc = Weed dry weight in the weedy check

The weed persistence index (WPI) was calculated by the given formula as suggested by Sarma (2016)

$$WPI = \frac{W_T}{W_C} \times \frac{WD_C}{WD_T}$$

Where, W_T and W_C = Weed biomass in treated and weedy check plot, respectively

WD_T and WD_C = Weed density in treated and weedy check plot, respectively

The per cent reduction of weed density (%RWD) and reduction of weed biomass (%RWB) were calculated as per the given formula as suggested by Islam *et al.* (2018)

$$\% RWD = \left(1 - \frac{\text{Number of weeds per m}^2 \text{in treated plot}}{\text{Number of weeds per m}^2 \text{ in weedy plot}}\right) \times 100$$

$$\% RWB = \left(1 - \frac{\text{Weed biomass per m}^2 \text{ in treated plot}}{\text{Weed biomass per m}^2 \text{ in weedy plot}}\right) \times 100$$

In the succeeding intercropping system, chickpea was considered as the main crop and linseed as an intercrop component. Then the grain yield of linseed from each plot was converted to chickpea equivalent yield of intercropping system as suggested by Agegnehu *et al.* (2006)

$$EY_L = Y_L \times \frac{P_1}{P_2}$$

$$EY_i = Y_c + EY_L$$

Where, EY_L= Chickpea equivalent yield of linseed (t/ha)

EY_i= Chickpea equivalent yield of intercropping system (t/ha)

Y_C and Y_L= Yield (q/ha) of chickpea and linseed respectively

P_1 and P_2= Price of linseed and chickpea respectively

RESULTS AND DISCUSSION

Weed density, weed biomass and weed control efficiency

The major weed flora with their relative composition observed in experimental field included *Echinochloa colona* (39.3 and 55.3%), *Ischaemum rugosum* (2.0 and 5.1%), *Dactyloctenium aegyptium* (2.2 and 2.9%), *Cynodon dactylon* (10.1 and 4.6%) among grasses; *Cyperus iria* (3.3 and 2.5%) among sedges, whereas among broad-leaf weeds, *Alternanthera sessilis* (15.2 and 6.7%), *Physalis minima* (1.9 and 2.8%), *Phyllanthus niruri* (2.6 and 4.4%), *Cyanotis axillaris* (3.2 and 2.6%) , *Eclipta alba* (9.6 and 4.9%) and *Cassia tora* (7.5 and 5.0%) during 2017 and 2018, respectively.

Significant variation in per cent reduction of weed density and biomass over control was observed among weed management practices at 30 and 60 DAS during both the years (**Table 2**). Among the herbicide treatments, the application of BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha) gave higher per cent reduction of weed density and biomass followed by BS + 2,4-DSS (WA) (25.0 + 678.75 g/ha), BS + 2,4-DSS (30.0 + 814.5 g/ha) and BS + 2,4-DSS (WA) (20.0 + 543.0 g/ha) (**Table 1**). Application of BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha) recorded the highest weed control efficiency followed by BS + 2,4-DSS (WA) (25.0 + 678.75 g/ha) during both the years at 30 DAS and 60 DAS (**Table 1**). The lowest weed control efficiency was found with the application of 2, 4- D EE (850 g/ha) at 30 and 60 DAS during both the years due to the poor control of grassy weeds by 2,4-D. The higher weed control efficiency recorded in *Kharif* 2017, may be attributed to the lower infestation of weeds as compared to *Kharif* 2018. The low infestation of weeds in *Kharif* 2017 was due to lower rainfall (398.40 mm) received during early growth period of crop up to 60 DAS when compared to the *Kharif* 2018 (587.60 mm).

Herbicide efficiency index and weed persistence index

Amongst herbicide, the maximum herbicide efficiency index (HEI) and minimum weed persistence index (WPI) were witnessed under the application of BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha) followed by BS + 2,4-DSS (WA) (25.0 + 678.75 g/ha) at 30 and 60 DAS, during both the years (**Table 2**). The application of 2,4-D EE recorded the minimum HEI and maximum WPI. Thus, there was an inverse relationship between HEI and WPI. Similar findings were also reported by Singh *et al.* (2017). As compared to 2018, in 2017, greater HEI was recorded at 30 DAS and 60 DAS, where as vice versa in case of WPI.

Yield and yield attributes

Among the herbicide treatments, the highest number of effective tillers/m^2, number of grains/ panicle, grain yield and the lowest sterility percentage was recorded under the application of BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha) (**Table 3**). The lowest grain yield was in weedy check treatment, with a reduction in grain yield of 51.0% in 2017 and 50.6% in 2018 as compare to weed free treatment. The lowest grain yield in weedy check might be due to season-long weed competition exerted by the weeds at the critical stages of crop growth. The weed free treatment recorded significantly higher grain yield (5.92 t/ha in 2017 and 5.75 t/ha in 2018) and was found at par with the application of BS+ 2, 4- DSS (WA) (30.0 + 814.5 g/ha), BS + 2, 4- DSS (WA) (25.0 + 678.75

Table 1. Effect of herbicides treatments on weed control efficiency (WCE), per cent reduction in weed density and biomass

Treatment	WCE (%)				Reduction in weed density (%)				Reduction in weed biomass (%)			
	30 DAS		60 DAS		30 DAS		60 DAS		30 DAS		60 DAS	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
BS + 2,4-DSS (20.0 + 543.0 g/ha)	79.2	77.0	79.0	75.9	60.9	62.5	53.4	50.5	79.2	77.0	79.0	75.9
BS + 2,4-DSS (25.0 + 678.75 g/ha)	84.3	80.5	79.6	77.8	66.9	67.6	59.4	55.9	84.3	80.5	79.6	77.8
BS + 2,4-DSS (30.0 + 814.5 g/ha)	88.6	87.7	85.4	84.4	80.0	81.2	70.9	67.4	88.6	87.7	85.4	84.4
BS + 2,4-DSS (WA) (20.0 + 543.0 g/ha)	87.7	86.4	84.6	82.7	77.4	79.7	67.7	63.6	87.7	86.4	84.6	82.7
BS + 2,4-DSS (WA) (25.0 + 678.75 g/ha)	96.8	94.2	90.6	90.2	85.4	84.8	76.4	75.2	96.8	94.2	90.6	90.2
BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha)	98.5	96.5	92.5	92.4	88.9	87.3	82.6	78.6	98.5	96.5	92.5	92.4
Bispyribac-sodium 10% SC (20 g/ha)	76.2	74.5	76.7	73.2	57.1	57.6	47.4	45.9	76.2	74.5	76.7	73.2
2,4-D-ethyl ester 38% EC (34% W/W) (850 g/ha)	62.2	58.7	66.5	61.2	44.6	44.8	23.0	35.3	62.2	58.7	66.5	61.2
Penoxsulam 21.7% SC (22.5 g/ha)	73.6	71.6	75.0	70.9	53.2	54.6	39.6	43.5	73.6	71.6	75.0	70.9
Weed free (20 and 40 DAS)	100.0	100.0	99.6	98.3	100.0	100.0	94.7	91.7	100.0	100.0	99.6	98.3
Weedy check	-	-	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DAS: Days after sowing; BS - Bispyribac-sodium; DSS - 2,4-D-sodium salt; WA - With adjuvant

Table 2. Effect of herbicides treatments on Herbicide efficiency index (HEI) and Weed persistence index (WPI)

Treatment	HEI				WPI			
	30 DAS		60 DAS		30 DAS		60 DAS	
	2017	2018	2017	2018	2017	2018	2017	2018
BS + 2,4-DSS (20.0 + 543.0 g/ha)	2.47	2.22	2.45	2.12	0.53	0.61	0.45	0.49
BS + 2,4-DSS (25.0 + 678.75 g/ha)	4.14	3.23	3.19	2.84	0.47	0.60	0.50	0.50
BS + 2,4-DSS (30.0 + 814.5 g/ha)	6.99	6.48	5.45	5.13	0.57	0.66	0.50	0.48
BS + 2,4-DSS (WA) (20.0 + 543.0 g/ha)	6.30	5.52	5.00	4.35	0.54	0.67	0.48	0.48
BS + 2,4-DSS (WA) (25.0 + 678.75 g/ha)	26.86	14.93	9.28	8.78	0.22	0.38	0.40	0.40
BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha)	65.59	28.59	13.30	13.05	0.14	0.27	0.43	0.36
Bispyribac-sodium 10% SC (20 g/ha)	1.61	1.33	1.65	1.26	0.56	0.60	0.44	0.50
2,4-D ethyl ester 38% EC (34% W/W) (850 g/ha)	0.62	0.59	0.69	0.63	0.68	0.75	0.43	0.60
Penoxsulam 21.7% SC (22.5 g/ha)	0.95	0.95	1.01	0.93	0.56	0.63	0.41	0.51

DAS: Days after sowing; BS - Bispyribac-sodium; DSS - 2,4-D-sodium salt; WA - With adjuvant

Table 3. Effect of herbicide treatments on rice yield attributes and yield of DSR and their residual effect on chickpea equivalent yield as succeeding crop

Treatment	No. of effective tillers/m^2		No. of grains/ panicle		Sterility percentage		Test weight (g)		Rice grain yield (t/ha)		Chickpea equivalent yield as succeeding crop (t/ha)		Net returns (×10^3 ₹/ha)		B:C ratio	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
BS + 2,4-DSS (20.0 + 543.0 g/ha)	381.7	371.3	124.5	121.0	12.4	12.8	24.3	24.2	4.39	4.29	2.31	2.16	44.0	52.5	1.6	1.9
BS + 2,4-DSS (25.0 + 678.75 g/ha)	382.3	375.3	127.2	123.3	11.4	11.9	24.4	24.4	4.79	4.63	2.31	2.25	49.3	58.5	1.7	2.1
BS + 2,4-DSS (30.0 + 814.5 g/ha)	412.7	407.3	138.7	135.5	8.7	9.4	24.7	24.7	5.20	5.11	2.36	2.28	56.9	67.1	2.0	2.3
BS + 2,4-DSS (WA) (20.0 + 543.0 g/ha)	412.0	406.8	137.7	134.7	9.1	9.5	24.4	24.4	5.14	4.97	2.33	2.27	54.7	64.7	1.9	2.3
BS + 2,4-DSS (WA) (25.0 + 678.75 g/ha)	415.0	407.5	140.7	136.7	8.3	9.0	24.7	24.7	5.43	5.28	2.38	2.29	59.5	70.0	2.1	2.4
BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha)	416.5	408.0	141.3	137.3	7.1	8.4	24.8	24.8	5.80	5.66	2.37	2.33	65.4	76.8	2.2	2.6
Bispyribac-sodium 10% SC (20 g/ha)	380.0	367.3	123.3	120.7	13.8	13.0	24.2	24.2	4.01	3.80	2.27	2.12	36.4	44.0	1.3	1.6
2,4-D-ethyl ester 38% EC (34% W/W) (850 g/ha)	326.2	320.8	110.3	108.7	17.8	18.4	24.1	24.0	3.57	3.53	2.23	2.00	32.3	39.4	1.2	1.5
Penoxsulam 21.7% SC (22.5 g/ha)	332.0	325.5	112.2	109.5	17.1	18.1	24.1	24.1	3.63	3.61	2.26	2.14	31.9	39.1	1.1	1.4
Weed free (20 and 40 DAS)	418.5	410.3	142.3	137.7	6.7	8.0	24.9	24.8	5.92	5.75	2.40	2.32	59.2	70.6	1.6	1.9
Weedy check	242.2	237.2	102.2	100.0	22.3	27.0	24.0	23.9	2.90	2.84	2.21	2.10	21.6	27.3	0.8	1.0
LSD (p=0.05)	7.6	5.7	6.6	3.8	3.3	1.5	NS	NS	0.84	0.86	NS	NS	-	-	-	-

DAS: Days after sowing; BS - Bispyribac-sodium; DSS - 2,4-D-sodium salt; WA - With adjuvant

g/ha), BS + 2, 4- DSS (30.0 + 814.5 g/ha) and BS + 2,4- DSS (WA) (20.0 + 543.0 g/ha) during both the years (**Table 3**). The highest grain yield was attributed to the higher reduction of weed density and biomass during both years. The bispyribac sodium inhibits the acetohydroxy acid synthase (ALS) to achieve a broad-spectrum control of weeds. Rao and Nagamani (2007) also reported that post-emergence application of bispyribac-sodium at 30 g/ha applied at 15 DAS was found to be the most effective due to its broad-spectrum control of weeds in rice, without any phytotoxic effect. On the other hand, 2,4-D EE controls broad-leaved weeds by inhibiting cell division (Das 2016). So the combination of both chemical stands more effective than their sole application against weed flora and fetched higher yield. No significant difference was observed in chickpea equivalent yield in chickpea + linseed intercrop, as succeeding crop

Phytotoxicity

The herbicide phytotoxicity effect was observed on rice during both the years but the crop recovered quickly. The application of BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha), BS + 2,4- DSS (WA) (25.0 + 678.75 g/ ha), BS+ 2,4-DSS (30.0 + 814.5 g/ha) and BS + 2, 4- DSS (25.0 + 678.75 g/ha) reported phytotoxicity in terms of chlorosis in rice crop at 3, 5 and 7 DAA with scale of 0 to 3 during both the years . Very low scale of 0 to 1 phytotoxicity was observed for necrosis and scorching with the application of BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha), BS + 2,4-DSS (WA) (25.0 + 678.75 g/ha) and BS + 2,4-DSS (30.0 + 814.5 g/ha) treatments.

Economics

Among different weed management practice, the highest net returns (₹ 65444 and 76762/ha) and B:C ratio (2.2 and 2.6) were recorded with application of BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha) during 2017 and 2018, respectively (**Table 3**). While, the lowest net returns (₹ 21620 and 27295/ha) and B:C ratio (0.8 and 1.0) were observed in weedy check. The weedy check treatment recorded 67 and 64 per cent loss in net returns during 2017 and 2018, respectively as compare to the application of BS+ 2,4-DSS (WA) (30.0 + 814.5 g/ha).

Thus it may be concluded that application of BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha) may be suggested for managing weeds in DSR as it controlled the weeds more effectively throughout the crop growth period and recorded higher gain yield, net returns and B:C ratio.

REFERENCES

Afrin N, Bhuiya M, Uddin MR, Bir H, Shahidul Mand Park KW. 2015. Combined effect of herbicides on the weed management of rice. *Research on Crops* **16** (3): 28–29.

Agegnehu G, Ghizaw A and Sinebo W. 2006. Yield performance and land-use efficiency of barley and faba bean mixed cropping in Ethiopian highlands. *European Journal of Agronomy* **25**(3): 202–207.

Chauhan BS. 2012. *Weed Management in Direct-Seeded Rice Systems*. International Rice Research Institute, Los Baños, 2p.

Chauhan BS, Mahajan G, Sardana V, Timsina J and Jat ML. 2012. Productivity and sustainability of the rice–wheat cropping system in the Indo-Gangetic Plains of the Indian subcontinent: problems, opportunities, and strategies. *Advances in Agronomy* **117**(2): 315–369.

Damalas CA, Dhima KV and Eleftherohorinos IG. 2005. Control of early watergrass (*Echinochloa oryzoides*) and late watergrass (*Echinochloa phyllopogon*) with cyhalofop, clefoxydim, and penoxsulam applied alone and in mixture with broad-leaf herbicides. *Weed technology* **20**(4): 992–998.

Das TK. 2016. *Weed Science Basics and Application*. Jain Brothers, New Delhi, 901p.

Hossain MM, Begum M, Rahman MM and Akanda MM. 2016. Weed management on direct-seeded rice system-a review. *Progressive Agriculture* **27** (1): 1–8.

Islam AM, Hia MAUH, Sarkar SK and Anwar MP. 2018. Herbicide based weed management in aromatic rice of Bangladesh. *Journal of the Bangladesh Agricultural University* **16** (1): 31–40.

Krishnamurty K, Rajashekara BG and Raghunatha G. 1975. Herbicidal efficiency index in sorghum. *Indian Journal of Weed Science* **7**(2): 75–79.

Menon MV, 2019. Herbicide mixtures for weed management in wet-seeded rice. *Indian Journal of Weed Science* **51**(3): 295–297.

Pathak H, Tewari AN, Sankhyan S, Dubey DS, Mina U, Singh VK and Jain N. 2011. Direct-seeded rice: potential, performance and problems-A review. *Current Advances in Agricultural Sciences* **3**(2): 77–88.

Rahman MM and Masood MM. 2012. Aerobic System: A potential water saving Boro rice production technology, pp 1-2. In: *National Conference* on *Adaptation of aerobic system for boro rice cultivation in farmer's field for saving irrigation water and attaining food security-Project*, Manilla, Philippines. International Rice Research Institute, Manilla.

Rao AN and Nagamani A. 2007. Available technologies and future research challenges for managing weeds in dry-seeded rice in India, pp 391–401. In: *Proceeding 21st Asian Pacific Weed Science Society* Conference, 2-6 October 2007, Colombo, Sri Lanka Asian Pacific Weed Science Society, Colombo.

Rao AN, Jhonson DE, Sivaprasad B, Ladha JK and Mortimer AM. 2007. Weed management in direct-seeded rice. *Advances in Agronomy* **93**: 153–255.

Rao AN, Wani SP, Ahmed S, Ali HH and Marambe B. 2017. An Overview of Weeds and Weed Management in Rice of South Asia. pp. 247 to 281. In: *Weed Management in Rice in the Asian-Pacific Region.* Asian-Pacific Weed Science Society (APWSS), (Eds. Rao AN and Matsumoto H), The Weed Science Society of Japan, Japan and Indian Society of Weed Science, India

Sarma A. 2016. *Numerical Agronomy*. Kalyani Publishers, Noida, 63p.

Singh VP, Singh SP, Bisht N, Kumar A, Satyawali K and Paliwal A. 2017. Assessment of post-emergence weed management in direct-seeded rice. *Indian Journal of Weed Science* **49** (3): 211–215.

Yadav RI, Singh MK, Singh RK and Nagargade M. 2018. Planting methods and weed management to improve yield in dry-seeded rice. *Indian Journal of Weed Science* **50**(1): 22–26.

Indian Journal of Weed Science **52**(3): 227–231, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Efficacy of pyribenzoxim herbicide in dry direct-seeded rice

Rajul Soni, Triptesh Mondal[1]*, Shobha Sondhia[2], Rajendra Prasad Sahu and Hradesh Patel

Department of Agronomy, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh 482 004, India

[1]Department of Agronomy, Faculty of Agriculture, Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar, West Bengal 736 165, India

[2]ICAR-Directorate of Weed Research, Jabalpur, Madhya Pradesh 482 004, India

**Email: mtriptesh@gmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00043.X

Type of article: Research article

Received : 7 March 2020
Revised : 24 August 2020
Accepted : 27 August 2020

Key words
Oxadiargyl
Post-emergence herbicide
Pyribenzoxim
Rice
Weed

ABSTRACT

A study was conducted at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh during *Kharif* 2017 and 2018 to evaluate the efficacy of pyribenzoxim herbicide in dry direct-seeded rice. Among the herbicidal treatments, pyribenzoxim 5% EC 60 g/ha was the most suitable for controlling weeds, followed by oxadiargyl 80% WP 100 g/ha, though hand weeding treatment showed lowest weed infestation and maximum grain yield (4.55 t/ha). Weed density and weed dry weight had strong negative correlation with grain yield ($r = -0.982^{**}$ and -0.983^{**}, respectively). Total weed population and biomass was the lowest in manually weeded plots followed by pyribenzoxim 5% EC 60 g/ha. The highest weed control efficiency (70.0, 86.7 and 88.3% at 30, 45 and 60 DAS, respectively), weed control index (82.9, 85.5 and 86.4% at 30, 45 and 60 DAS, respectively) and herbicide efficiency index (43.4%) were found with pyribenzoxim 5% EC 60 g/ha. The pyribenzoxim 5% EC 60 g/ha at 15 DAS was found the most remunerative with benefit-cost ratio of 2.42.

INTRODUCTION

Rice (*Oryza sativa* L.) plays a significant role in the economy of India and occupies central position in national agricultural policy and food security. Direct-seeded rice (DSR) is gaining popularity as an alternative to puddled transplanted rice. It allows early establishment of the succeeding wheat crop and ensures higher profit in areas with assured water supply. Weed infestation is however one of the limiting factors in DSR. The yield losses due to weeds are greater in DSR than the transplanted rice in the absence of effective weed control options (Singh *et al.* 2018). Generally pre-emergence herbicides like pretilachlor, butachlor, anilophos and post-emergence herbicides like 2,4-D, bispyribac-sodium and metsulfuron-methyl + chlorimuron-ethyl are being used frequently for broad-spectrum weed control in DSR. Continuous application of same herbicide also results in weed flora shift and development of herbicide resistance in weeds. Hence, there is always a need to develop and evaluate alternate herbicides to overcome these problems. Keeping in view the above constraints, a field experiment was undertaken to study the efficacy of a new post-emergence herbicide 'pyribenzoxim' in DSR for broad-spectrum weed control.

MATERIALS AND METHODS

The field experiment was conducted at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh during *Kharif* 2017 and 2018. During the crop growing period, minimum and maximum temperature varied between 12.2^{0}C and 33.8^{0}C and the total rainfall was 850.5 mm. The experimental soil (0-15 cm soil layer) was sandy loam in texture with pH 6.83, organic carbon (C) 0.79%, mineralizable nitrogen (N) 180.29 kg/ha, phosphorus (P) 19.50 kg/ha and NH_4OAc extractable potassium (K) 169.10 kg/ha. Eight weed management treatments comprised of pyribenzoxim 5% EC 25 g/ha, pyribenzoxim 5% EC 30 g/ha, pyribenzoxim 5% EC 35 g/ha, pyribenzoxim 5% EC 60 g/ha, fenoxaprop-p-ethyl 6.7% EC 56.95 g/ha, oxadiargyl 80% WP 100 g/ha, hand weeding and weedy check were replicated thrice in a randomized block design (RBD). The size of each plot was 5.25 × 3.60 m. Herbicides were sprayed as post-emergence at 15 days after sowing (DAS) *i.e.*, 2-3 leaf stage of rice. Hand weeding was done twice at 20 and 40 DAS. Dry DSR was practiced under rice-wheat cropping system with an early maturing (110-115 days) rice variety '*MTU 1010*' which is suitable for cultivation in Madhya Pradesh. Sowing of seeds was done in rows 20 cm apart with a seed-cum-fertilizer drill in an unpuddled field on 4th July during both the years. A fertilizer dose of 120:60:40 kg/ha N:P:K, and seed rate of 60 kg/ha was used. Half dose of N, full dose of P and K was applied as basal at the time of sowing, one-fourth of N was top-dressed during active tillering (30-45 DAS) and remaining one-fourth of N was top-dressed at panicle initiation stage (60 DAS). The crop was irrigated twice just before N top-dressing.

Weed control efficiency (WCE) and weed control index (WCI) were worked out by the formulas suggested by Das (2013).

Herbicide efficiency index (HEI) was calculated based on the weed killing potential of different herbicide treatments as per formula (Krishnamurthy *et al.* 1995):

$$\text{HEI (\%)} = \frac{\text{Yield in treatment plot-yield in control plot}}{\text{Yield in control plot}} \times 100$$

Gross returns, net returns and benefit-cost (B:C) ratio were calculated by taking market price of rice grain (₹ 14.50/kg in 2017 and ₹ 15.50/kg in 2018) and rice straw (₹ 1.00/kg in 2017 and 2018). All the data were analyzed by analysis of variance (ANOVA) method with SPSS software. The differences between treatment means were tested at the significance level of 5%.

RESULTS AND DISCUSSION

Dominant weed flora in DSR

The dominant weed flora observed at the experimental field contained *Echinochloa colona* (barnyard grass), *Digitaria sanguinalis* (large crab grass), *Alternanthera sessilis* (khaki weed), *Physalis minima* (ground cherry), *Cyperus rotundus* (purple nut sedge) and *Cyperus iria* (flat sedge). Among these weeds, *D. sanguinalis* was the most dominant at 60 DAS during the first year and *A. sessilis* during the second year. Pandey *et al.* (2010) reported that *A. sessilis* was one of the most pre-dominant broad-leaved weed species in DSR in Jabalpur, Madhya Pradesh. *C. rotundus* was more rampant than *C. iria* due to its continuous regrowth during the crop season.

Weed density and weed dry weight

After spraying of herbicides, weed density was the highest in weedy check at 15, 30 and 45 days after herbicide application (DAA) and the lowest in hand weeded plots followed by pyribenzoxim 5% EC 60 g/ha. Application of pyribenzoxim 5% EC 60 g/ha lowered the weed population by 54.8, 58.8 and 60.2% for grasses, 26.2, 66.5 and 67.2% for broad-leaved weeds and 61.0, 62.7 and 64.7% for sedges at 15, 30 and 45 DAA, respectively as compared to untreated control **(Table 1)**. Application of pyribenzoxim 5% EC 60 g/ha reduced total weed density by 57 to 85% **(Table 3)**. This result was in accordance with the report of Gu *et al.* (2006). Hand weeding witnessed the lowest weed dry weight followed by the pyribenzoxim 5% EC treated plots where weed dry weight decreased by 53.5, 58.4 and 61.2% for grassy weeds, 57.3, 61.8 and 63.0% for broad-leaved weeds and 60.9, 60.5 and 63.5% for sedges at 15, 30 and 45 DAA, respectively **(Table 2)**. Moon *et al.* (1998) also reported much lower total weed dry weight in pyribenzoxim applied plots than control plots **(Table 3)**. The results also revealed that broad-leaved weeds had the highest dry weight followed by sedges and grasses at 15, 30 and 45 DAA in un-treated plots. Among all the herbicidal treatments, the lowest weed dry weight was recorded with pyribenzoxim 5% EC 60 g/ha. Hand weeding twice at 20 and 40 DAS had the lowest weed density and dry weight. Post-emergence application of fenoxaprop-p-ethyl 6.7% EC 56.95 g/ha resulted in good control on grassy weeds as demonstrated by Singh *et al.* (2016) and sedges, by reducing their population and biomass production but was not effective on broad-leaved weeds.

Weed control efficiency, weed control index, weed index and herbicide efficiency index

Among the herbicides, the highest weed control efficiency (WCE) and weed control index (WCI) were noticed with pyribenzoxim 5% EC 60 g/ha and the lowest in fenoxaprop-p-ethyl 6.7% EC 56.95 g/ha. Similar findings were also observed by Moon *et al.* (1998) and Ma *et al.* (2014). However, oxadiargyl 80% WP 100 g/ha treatment had better weed controlling ability than the lower doses of pyribenzoxim 5% EC **(Table 4)**. Among the chemical weed management options, the lowest weed index (4.8%) was recorded with post-emergence application of pyribenzoxim 5% EC 60 g/ha closely followed by oxadiargyl 80% WP 100 g/ha (6.0%). Lower WI indicated the superiority of these two treatments in higher magnitude of weed suppression with increased grain yield and selectivity to rice. Herbicide efficiency index (HEI) was maximum in foliar application of pyribenzoxim 5% EC 60 g/ha (43.4%) followed by oxadiargyl 80% WP 100 g/ha (41.6%). It was also observed that hand weeding twice at 20 and 40 DAS was superior among all the treatments in reducing weed growth with the highest WCE (79.2%, 95.6% and 97.2% at 30, 45 and 60

Table 1. Effect of different weed management options on density of grasses, broad-leaved weeds and sedges (pooled data of 2 years)

Treatment	Weed density (no./m^2) Grassy weeds				Broad-leaved weeds				Sedge weeds			
	Before spray	15 DAA	30 DAA	45 DAA	Before spray	15 DAA	30 DAA	45 DAA	Before spray	15 DAA	30 DAA	45 DAA
Pyribenzoxim 5% EC 25 g/ha	8.1 (64.8)	4.7 (21.5)	4.7 (20.8)	4.4 (18.7)	8.2 (66.8)	6.4 (39.8)	4.6 (20.0)	4.4 (18.4)	7.8 (59.1)	4.2 (16.4)	4.0 (15.3)	4.0 (14.7)
Pyribenzoxim 5% EC 30 g/ha	8.1 (64.9)	4.5 (19.3)	4.4 (18.5)	4.2 (16.7)	8.4 (70.2)	6.7 (44.1)	4.3 (17.5)	4.2 (16.3)	7.7 (58.5)	3.9 (14.3)	3.8 (13.4)	3.6 (12.0)
Pyribenzoxim 5% EC 35 g/ha	8.1 (65.1)	4.5 (19.1)	4.4 (18.3)	4.2 (16.5)	8.5 (70.4)	6.7 (43.7)	4.3 (17.3)	4.1 (16.0)	7.7 (58.3)	3.9 (14.2)	3.8 (13.3)	3.6 (11.8)
Pyribenzoxim 5% EC 60 g/ha	8.1 (64.8)	3.7 (12.7)	3.6 (11.8)	3.3 (10.4)	8.5 (70.7)	6.3 (38.4)	2.9 (7.7)	2.9 (7.3)	7.7 (58.0)	3.1 (8.6)	3.0 (8.1)	2.9 (7.3)
Fenoxaprop-p-ethyl 6.7% EC 56.95 g/ha	8.1 (64.5)	4.5 (19.0)	4.4 (17.9)	4.2 (16.8)	8.5 (71.2)	8.4 (70.2)	8.5 (72.0)	8.7 (74.9)	7.5 (54.5)	4.1 (15.5)	4.0 (14.7)	3.8 (13.3)
Oxadiargyl 80% WP 100 g/ha	8.1 (65.0)	4.4 (18.3)	4.3 (17.2)	4.1 (15.9)	8.5 (70.3)	6.6 (42.2)	4.2 (16.4)	3.9 (14.1)	7.7 (58.3)	3.8 (13.3)	3.7 (12.9)	3.6 (12.0)
Hand weeding	8.1 (65.2)	2.0 (2.8)	1.9 (2.5)	1.7 (2.0)	8.4 (70.1)	6.2 (36.7)	2.2 (3.8)	1.8 (2.4)	7.8 (59.8)	1.9 (2.5)	1.9 (2.6)	1.6 (1.6)
Weedy check	8.1 (64.8)	8.2 (66.0)	8.3 (67.3)	8.3 (68.5)	8.5 (70.3)	8.6 (72.6)	8.8 (76.0)	8.8 (76.3)	7.8 (59.6)	7.9 (62.0)	8.1 (64.0)	8.2 (66.0)
LSD (p=0.05)	NS	0.78	0.71	0.57	NS	1.06	0.88	0.94	NS	0.81	0.78	0.74

DAA - Days after application; Figures in the parentheses are original values. Data subjected to $(\sqrt{x+1})$ square root transformation

Table 2. Effect of different weed management options on dry weight of grasses, broad-leaved weeds and sedges (pooled data of 2 years)

Treatment	Weed dry weight (g/m^2) Grassy weeds				Broad-leaved weeds				Sedge weeds			
	Before spray	15 DAA	30 DAA	45 DAA	Before spray	15 DAA	30 DAA	45 DAA	Before spray	15 DAA	30 DAA	45 DAA
Pyribenzoxim 5% EC 25 g/ha	5.8 (32.1)	4.0 (14.6)	4.5 (19.2)	4.4 (19.0)	6.1 (36.1)	4.5 (19.3)	4.8 (21.9)	5.0 (23.5)	7.8 (59.1)	3.6 (11.8)	4.1 (15.6)	4.3 (17.7)
Pyribenzoxim 5% EC 30 g/ha	5.8 (32.4)	3.7 (12.6)	4.3 (17.2)	4.2 (16.5)	6.1 (36.2)	4.3 (17.4)	4.5 (19.6)	4.7 (20.8)	7.7 (58.5)	3.4 (10.2)	3.9 (14.0)	4.1 (16.0)
Pyribenzoxim 5% EC 35 g/ha	5.8 (32.6)	3.7 (12.4)	4.2 (16.9)	4.0 (16.3)	6.0 (35.4)	4.3 (17.2)	4.5 (19.3)	4.7 (21.2)	7.7 (58.3)	3.3 (9.9)	3.8 (13.7)	4.1 (15.7)
Pyribenzoxim 5% EC 60 g/ha	5.8 (32.7)	3.0 (8.2)	3.2 (9.5)	3.2 (9.3)	6.1 (35.8)	3.4 (10.3)	3.4 (10.8)	3.5 (11.4)	7.7 (58.0)	2.7 (6.1)	3.1 (8.5)	3.3 (10.1)
Fenoxaprop-p-ethyl 6.7% EC 56.95 g/ha	5.8 (32.9)	3.7 (12.5)	3.4 (10.2)	3.5 (11.3)	6.2 (37.7)	7.6 (56.0)	8.3 (67.0)	9.0 (79.6)	7.7 (58.5)	3.5 (11.2)	4.00 (14.9)	4.2 (16.7)
Oxadiargyl 80% WP 100 g/ha	5.8 (32.3)	3.5 (11.5)	3.8 (13.6)	4.0 (14.8)	6.0 (35.2)	4.0 (14.6)	4.2 (16.6)	4.5 (19.2)	7.7 (58.3)	3.3 (9.9)	3.8 (13.2)	4.0 (15.2)
Hand weeding	5.8 (32.2)	1.6 (1.6)	1.8 (2.1)	1.6 (1.5)	6.0 (34.9)	2.1 (3.3)	2.0 (3.2)	1.9 (2.5)	7.8 (59.8)	1.8 (2.2)	1.9 (2.7)	1.8 (2.1)
Weedy check	5.8 (32.6)	6.5 (40.6)	7.8 (59.5)	8.3 (67.5)	6.0 (35.0)	7.9 (60.7)	9.0 (79.4)	9.5 (89.5)	7.8 (59.6)	6.8 (45.5)	8.0 (62.7)	9.2 (82.6)
LSD (p=0.05)	NS	0.79	0.74	0.72	NS	0.85	0.77	0.83	NS	0.65	0.78	0.80

Figures in the parentheses are original values. Data subjected to $(\sqrt{x+1})$ square root transformation; DAA - Days after application

DAS, respectively), WCI (95.1, 96.0 and 97.4% at 30, 45 and 60 DAS, respectively) and HEI (50.5%).

Growth and yield components and grain yield of direct-seeded rice

The growth components of rice varied significantly with different weed management practices **(Table 5)**. The highest plant height (86.4 cm) at harvest was recorded with hand weeding closely followed by pyribenzoxim 5% EC 60 g/ha (85.1 cm). Untreated control recorded the lowest plant height (71.0 cm) at harvest. At 90 DAS, the maximum number of tillers/m^2 was recorded in hand weeding (303.7) followed by the highest dose of pyribenzoxim 5% EC (285.3). Tiller density was 42.2% higher with foliar application of pyribenzoxim 5% EC 60 g/ha than weedy check. Leaf area index (LAI) was found maximum in hand weeded plots (4.28) followed by pyribenzoxim 5% EC 60 g/ha at 15 DAS (4.19). Due to higher weed infestation, LAI was greatly reduced in un-weeded control (2.90). The highest number of panicles/m^2 at harvest (246.0) was found in manually-weeded condition. Spraying of pyribenzoxim 5% EC 60 g/ha at 2-3 leaf stage of rice resulted in 48.9% increase in number of panicles/m^2 at harvest over untreated control, though the highest increment (50.7%) was observed in oxadiargyl 80% WP 100 g/ha **(Table 5)**. Weed controlling treatments provided 25.4-50.2% higher grain yield than weedy check. With the application of pyribenzoxim 5% EC at different doses, the grain yield of rice increased from 30.4-42.9% over weedy check. These results were similar with the report of Gu *et al.* (2006).

Correlation matrix

Weed density and dry weight had significant negative correlation with all the yield components except test weight **(Table 6)**. Number of panicles/m^2, panicle length (cm) and number of filled grains/panicle had strong significant positive correlation with grain yield of rice (r = 0.990**, 0.887** and 0.895**, respectively). But weed density and dry weight had highly significant negative correlation with grain yield of rice (r = -0.982** and -0.983**,

Table 3. Effect of different weed management options on total density and total dry weight of grasses, broad-leaved weeds and sedges (pooled data of 2 years)

Treatment	Total weed density (no./m^2)				Total weed dry weight (g/m^2)			
	Before spray	15 DAA	30 DAA	45 DAA	Before spray	15 DAA	30 DAA	45 DAA
Pyribenzoxim 5% EC 25 g/ha	8.0(63.6)	5.2(25.9)	4.4(18.7)	4.3(17.2)	6.6(42.9)	4.0(15.2)	4.1(18.9)	4.6(20.0)
Pyribenzoxim 5% EC 30 g/ha	8.1(64.5)	5.2(25.9)	4.2(16.5)	4.0(15.0)	6.6(42.4)	3.8(13.4)	4.2(16.9)	4.3(17.7)
Pyribenzoxim 5% EC 35 g/ha	8.1(64.6)	5.2(25.7)	4.2(16.3)	4.0(14.8)	6.6(42.1)	3.8(13.3)	4.2(16.6)	4.3(17.7)
Pyribenzoxim 5% EC 60 g/ha	8.1(64.5)	4.6(19.9)	3.0(9.2)	3.0(8.2)	6.6(42.1)	3.0(8.1)	3.3(9.6)	3.4(10.6)
Fenoxaprop-p-ethyl 6.7% EC 56.95 g/ha	8.0(63.4)	6.0(34.9)	6.0(34.9)	6.0(35.0)	6.6(43.0)	5.3(26.5)	5.6(30.7)	6.1(35.9)
Oxadiargyl 80% WP 100 g/ha	8.1(64.5)	5.1(24.6)	4.1(15.5)	3.9(14.0)	6.6(41.9)	3.5(12.0)	3.9(14.5)	4.2(16.4)
Hand weeding	8.1(65.0)	3.9(14.0)	2.0(3.0)	1.7(2.0)	6.6(42.3)	1.8(2.4)	1.9(2.6)	1.7(2.0)
Weedy check	8.1(64.9)	8.2(66.9)	8.4(69.1)	8.4(70.3)	6.6(42.4)	7.1(48.9)	8.3(67.2)	8.9(78.9)
LSD (p=0.05)	NS	0.57	0.45	0.40	NS	0.47	0.42	0.45

Figures in the parentheses are original values. Data subjected to $(\sqrt{x+1})$ square root transformation; DAA - Days after application

Table 4. Weed control efficiency (WCE), Weed control index (WCI), Weed index (WI) and Herbicide efficiency index (HEI) as influenced by different weed management options in direct-seeded rice (mean data of 2 years)

Treatment	WCE (%)			WCI (%)			WI (%)	HEI (%)
	15 DAA	30 DAA	45 DAA	15 DAA	30 DAA	45 DAA		
Pyribenzoxim 5% EC 25 g/ha	61.3	72.7	75.6	68.9	72.2	74.6	13.2	30.3
Pyribenzoxim 5% EC 30 g/ha	61.4	76.2	78.6	72.3	74.9	77.2	8.0	38.4
Pyribenzoxim 5% EC 35 g/ha	61.5	76.4	79.0	72.3	75.4	77.5	6.7	40.7
Pyribenzoxim 5% EC 60 g/ha	70.0	86.7	88.3	82.9	85.5	86.4	4.8	43.4
Fenoxaprop-p-ethyl 6.7% EC 56.95 g/ha	47.3	49.5	50.1	45.1	53.9	54.5	16.4	25.6
Oxadiargyl 80% WP 100 g/ha	63.6	77.6	79.9	75.3	78.4	79.3	6.0	41.6
Hand weeding	79.2	95.6	97.2	95.1	96.0	97.4	0.0	50.5
Weedy check	0.0	0.0	0.0	0.0	0.0	0.0	33.3	0.0

DAA - Days after application

Table 5. Growth and yield components and grain yield of direct-seeded rice as influenced by different weed management options (pooled data of 2 years)

Treatment	Growth component			Yield component				Grain yield (t/ha)		
	Plant height at harvest (cm)	No. of tillers/m^2 at 90 DAS	LAI at 90 DAS	No. of panicles/m^2 at harvest	Panicle length at harvest (cm)	No. of filled grains/panicle	Test weight (g)	2017	2018	Pooled data
Pyribenzoxim 5% EC 25 g/ha	80.4	260.7	3.50	204.3	17.6	80.00	26.87	3.79	4.10	3.95
Pyribenzoxim 5% EC 30 g/ha	82.9	270.0	4.10	217.7	17.9	81.67	26.27	4.13	4.24	4.19
Pyribenzoxim 5% EC 35 g/ha	83.0	273.3	4.11	213.7	18.9	82.67	26.95	4.25	4.24	4.24
Pyribenzoxim 5% EC 60 g/ha	85.1	285.3	4.19	223.3	18.8	82.33	26.51	4.34	4.32	4.33
Fenoxaprop-p-ethyl 6.7% EC 56.95 g/ha	75.1	259.3	3.45	195.0	17.7	80.33	26.10	3.64	3.97	3.80
Oxadiargyl 80% WP 100 g/ha	84.5	278.0	4.16	226.0	18.3	82.00	26.23	4.42	4.13	4.27
Hand weeding	86.4	303.7	4.28	246.0	19.0	83.00	26.00	4.57	4.53	4.55
Weedy check	71.0	200.7	2.90	150.0	17.0	79.33	27.15	3.09	2.98	3.03
LSD (p=0.05)	3.3	45.0	0.45	42.5	NS	NS	NS	0.46	0.37	0.30

DAS – Days after sowing; LAI – Leaf area index

Table 6. Correlation matrix among weed density, weed dry weight, grain yield and yield components of direct-seeded rice (mean data of 2 years)

Treatment	Weed density (no./m^2)	Weed dry weight (g/m^2)	Grain yield (t/ha)	No. of panicles/m^2	Panicle length (cm)	No. of filled grains/panicle	Test weight (g)
Weed density (no./m^2)	1						
Weed dry weight (g/m^2)	.998**	1					
Grain yield (t/ha)	-.982**	-.983**	1				
No. of panicles/m^2	-.969**	-.971**	.990**	1			
Panicle length (cm)	-.822*	-.818*	.887**	.853**	1		
No. of filled grains/panicle	-.815*	-.808*	.895**	.870**	.964**	1	
Test weight (g)	.511	.549	-.456	-.496	-.199	-.160	1

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

Table 7. Production economics of direct-seeded rice as influenced by different weed management options (mean data of 2 years)

Treatment	Gross returns (×10^3 ₹/ha)			Net returns (×10^3 ₹/ha)			B:C ratio		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
Pyribenzoxim 5% EC 25 g/ha	61.56	70.46	66.01	32.65	41.55	37.10	2.13	2.44	2.28
Pyribenzoxim 5% EC 30 g/ha	66.82	72.45	69.63	37.76	43.39	40.57	2.30	2.49	2.40
Pyribenzoxim 5% EC 35 g/ha	68.50	72.51	70.50	39.29	43.30	41.29	2.34	2.48	2.41
Pyribenzoxim 5% EC 60 g/ha	70.39	74.49	72.44	40.43	44.53	42.48	2.35	2.49	2.42
Fenoxaprop-p-ethyl 6.7% EC 56.95 g/ha	59.52	68.39	63.95	30.30	39.17	34.73	2.04	2.34	2.19
Oxadiargyl 80% WP 100 g/ha	70.34	70.42	70.38	41.18	41.26	41.22	2.41	2.41	2.41
Hand weeding	73.87	78.09	75.98	36.21	40.43	38.32	1.96	2.07	2.02
Weedy check	50.34	51.46	50.90	22.68	23.80	23.24	1.82	1.86	1.84

respectively). This result was in agreement with the findings of Mondal *et al.* (2019).

Production economics

Gross returns were higher than cultivation costs in all the weed management options including un-weeded control. The highest net returns (₹ 42,480/ha) and benefit-cost ratio (2.42) were obtained from pyribenzoxim 5% EC 60 g/ha spraying treatment **(Table 7)**. Hand weeding treatment provided maximum gross returns (₹ 75,980/ha) but high labour wages made it costly by reducing the net returns than herbicide applied treatments. This result was in line with the findings of Maity and Mukherjee (2009).

Based on this field study, it can be concluded that foliar application of pyribenzoxim 5% EC 60 g/ha at 15 DAS as post-emergence would be the most effective for controlling the weed flora in dry direct-seeded rice.

REFERENCES

Chakraborti M, Duary B and Datta M. 2017. Effect of weed management practices on nutrient uptake by direct seeded upland rice under Tripura condition. *International Journal of Current Microbiology and Applied Sciences* **6**(12): 66–72.

Das TK. 2013. *Weed Science Basics and Applications*. Jain Brothers, New Delhi.

Gnanavel I and Kathiresan RM. 2002. Sustainable weed management in rice-rice cropping system. *Indian Journal Weed Science*, **34**(3&4): 192–196.

Gu SJ, Koo SJ and Pitoon K. 2006. Efficacy of post-emergence herbicide pyribenzoxim in wet direct-seeded rice in Thailand. *Korean Journal of Weed Science* **26**(1): 89–97.

Krishnamurthy K, Rajshekara BG, Raghunatha G, Jagannath MK and Prasad TVR. 1975. Herbicide efficiency index in sorghum. *Indian Journal of Weed Science* **7**(2): 75-79.

Ma GL, Bai LY, Liu DC, Liu XY, Tang T and Peng YJ. 2014. Control of herbicide resistant *Echinochloa crusgalli* in direct-seeded rice crops. *Acta Prataculturae Sinica* **23**(6): 259–265.

Maity SK and Mukherjee PK. 2009. Integrated weed management practices in dry direct-seeded summer rice (*Oryza sativa*). *Indian Journal of Agricultural Sciences* **79**(12): 976–979.

Mondal D, Ghosh A, Bera S, Ghosh R and Bandopadhyay P. 2019. Eco-efficacy of pretilachlor 50% EC in transplanted winter rice and its residual effect on lentil. *Indian Journal of Weed Science* **51**(3): 220–226.

Moon BC, Park ST, Kim SY, Kim SC and Oh YJ. 1998. Herbicidal efficacy of cyhalofop/bentazon and pyribenzoxim as affected by application time in dry-seeded rice. *Korean Journal of Weed Science* **18**(1): 28–35.

Pandey MP, Verulkar SB and Sharma D. 2010. Rice research: past achievements, present scenario and future thrust. *Indian Journal of Agricultural Sciences*, **34**(1-2): 36–38.

Singh SP, Paikra KK and Patel CR. 2018. Direct seeded rice: A resource conservation technology for increasing productivity and profitability of aerobic rice (*Oryza sativa* L.) in Raigarh district of Chhattisgarh plains. *International Journal of Agriculture Sciences* **10**(10): 6174–6176.

Singh VP, Singh SP, Dhyani VC, Banga A, Kumar A, Satyawali K and Bisht N. 2016. Weed management in direct-seeded rice. *Indian Journal of Weed Science* **48**(3): 233–246.

Indian Journal of Weed Science **52**(3): 232–236, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Assessing bio-efficacy potential of herbicide combinations for broad-spectrum weed control in late-sown wheat

Vasudev Meena*, M.K. Kaushik[1], M.L. Dotaniya[2] and H. Das

ICAR-Indian Institute of Soil Science, Bhopal, Madhya Pradesh 462 038, India

[1]Department of Agronomy, Rajasthan College of Agriculture, Udaipur, Rajasthan 313 001, India

[2]ICAR- Directorate of Rapeseed-Mustard Research, Bharatpur, Rajasthan 321 303, India

**Email: vasu_maheshin84@rediffmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00044.1

Type of article: Research article

Received : 15 May 2020

Revised : 21 September 2020

Accepted : 24 September 2020

Key words

Bio-efficacy

Ready-mix

Triticum aestivum L.

Weed

Weed control index

Yield

ABSTRACT

A field experiment was conducted during 2015-16 and 2016-17 at Rajasthan College of Agriculture, Udaipur, India with the objective to assess bio-efficacy potential of the ready-mix herbicides against complex weed flora in wheat. The experiment consisting of fifteen treatments, was laid out in a randomized block design with four replications. The results indicated significant reduction in population and growth of weeds by ready-mix application of sulfosulfuron + metsulfuron (32.0 g/ha) and mesosulfuron + iodosulfuron (14.4 g/ha) followed by clodinafop + metsulfuron (64.0 g/ha), pinoxaden + metsulfuron (64.0 g/ha) over other weed control treatments. However, two hand weeding (30 and 45 DAS) registered maximum decline in density and dry biomass of all the weeds. Moreover, herbicides combination sulfosulfuron + metsulfuron and mesosulfuron + iodosulfuron attributed to greater value of weed control index (WCI) with maximum reduction of weed density and dry biomass. At 60 DAS, the array of WCI ranged from 9.19 to 95.01 and 57.48 to 97.01% for monocots and dicots, respectively and resulted into higher grain yield (34.3 and 20.5% more), net returns (49.1 and 47.7% more) and B-C ratio (2.34 and 2.32) over the unweeded control. The study concluded that the use of sulfosulfuron + metsulfuron (32.0 g/ha) and mesosulfuron + iodosulfuron (14.4 g/ha) as post-emergence at 5 WAS provided efficacious control of all sorts of weeds in wheat with higher yield and net returns.

INTRODUCTION

Weeds are one of the major biotic constraints not only in the wheat production but in other crops also as they compete with crops for nutrients, moisture, light and space (Chhokar *et al.* 2012). Weeds possess many growth characteristics and adaptations which enable them to successfully exploit the numerous ecological niches (Zimdahl 2013). Weeds suppress the crop growth in the early stages which results in reduction of yield (Verma *et al.* 2015). Fahad *et al.* (2015) opined that allowing weeds to grow with wheat at the beginning of the season has a greater negative impact on crop yield than allowing the weeds to grow in the crop later in the season. In late-sown wheat, the reduction in grain yield due to mixed weed flora was reported up to 34.3% which leads to the loss of 2.57, 0.43 and 1.27% of NPK (Meena *et al.* 2017a, b, 2019). Wheat is infested with grassy as well as broad-leaved weeds. To control mixed population of weeds and to avoid herbicide resistance and weed flora shift by continuous use of single herbicide, compatible mixtures can be employed (Das and Yaduraju 2012). Under such circumstances, mix or sequential application of herbicides with different selectivity can widen the range of weed control, save time, application cost and reduce impact of herbicides on environment, resulting in biological activity higher than their individual applications (Sharma *et al.* 2015). Application of tank-mix herbicides may result in better control of weeds due to possible synergistic actions (Das and Yaduraju 2012, Susha *et al.* 2014). Tank-mix or pre-mix application of pre- and post-emergence herbicide at different time showed effective weed control. Besides controlling mixed weed flora, the integrated use of herbicides may help in managing herbicide resistance problems. Keeping above facts in view, an investigation was carried out with the objective to assess the efficacy of herbicide combinations for broad spectrum weed control in wheat.

MATERIALS AND METHODS

The study was consisting of two experiments that conducted during *Rabi* season of 2015-16 and 2016-17 at the Rajasthan College of Agriculture, Udaipur (India) which is situated at 24°5' N latitude and 74°42' E longitude with an altitude of 582.17 m above mean sea level. The region falls under NARP agro climatic zone IVa (Sub-Humid Southern Plains and Arawali Hills) of Rajasthan (India).The soil of the experimental site was clay loam in texture, non-saline and slightly alkaline in reaction. The soil was low in available nitrogen, medium in organic carbon and phosphorus and high in available potassium. The experiment consists of fifteen treatments that were tested on the wheat crop variety '*Raj- 3765*'. All the treatments were replicated four times in a randomize block design. The crop was sown on 10th December, 2015 during first year and 12th December, 2016 during the second year at a row spacing of 22.5 cm with a recommended seed rate of 125 kg/ha. The crop was supplied with 90 kg N and 35 kg P/ha through urea and di-ammonium phosphate (DAP). Half dose of nitrogen and full dose of phosphorus were applied as basal at the time of sowing while remaining half dose of nitrogen was top dressed in two equal splits at the time of first and second irrigation.

The herbicides were sprayed with battery operated knapsack sprayer fitted with flat-fan nozzle using spray volume of 500 L/ha. The observations were taken on different weed parameters during crop growth period. Data on density and dry matter of weeds were recorded at 60 DAS under each treatment with the help of 0.25 m^2 quadrate selected randomly in each plot. After identification, the weed species were categorized into monocots and dicots. Weed density was calculated on the basis of the total number of an individual weed species/m^2 and weed control index were computed using the standard procedure as following details:

To compare the different treatments of weed control on the basis of dry weight, weed control index (WCI) was calculated as follows. It indicates the per cent reduction in the dry weight in treated plots compared to weedy plots.

$$\text{WCI (\%)} = \frac{\text{WDc} - \text{WDt}}{\text{WDc}} \text{X } 100$$

Where, WD_C is the weed dry matter in unweeded control (g/m^2) and WDt is the weed dry matter in treated plot (g/m^2).

Data were subjected to the statistical analysis by using SAS 9.3. Analysis of variance was performed using PROCGLM after square root transformation ($\sqrt{x+0.5}$) of the original data as appropriate for weed density and dry weight to hold the normality assumption, where, x is the observed value and 0.5 is a constant. The treatment means were separated at p=0.05.

RESULTS AND DISCUSSION

Weed species

The field was severely infested with both grassy as well as broad-leaf weeds. The population of broad-leaf weeds was more (91%) as compared to monocots (9%). Among the dicots, *Melilotus indica* was more prominent with highest density (45%) followed by *Fumaria parviflora* (15%), *Chenopodium album* (9%), *Chenopodium murale* (6%), *Convolvulus arvensis* (5%) and others dicots (11%) (*Anagallis arvensis*, *Spergulla arvensis* and *Coronopus didymus*) with *Phalaris minor* (9%) only species under monocots.

Effect on weed density and weed dry matter

Different weed management options significantly reduced the density and dry weight of monocot and dicot weeds over unweeded control. The highest density of different weeds was observed in unweeded control whereas two hand weeding recorded lowest pooled density (**Table 1**). The per cent reduction in pooled density of dicots (*Melilotus indica*, *Fumaria parviflora*, *Chenopodium murale*, *Chenopodium album* and *Convolvulus arvensis*) was varied from 59.25 to 95.30, 44.30 to 88.36, 11.36 to 93.13, 45.08 to 90.89 and 23.12 to 91.64%, respectively as lowest in pendimethalin to highest in two hand weeding. Similarly, the reduction in weed density of monocot (*Phalaris minor*) ranged between 16.65-87.70% among the treatments. Further, the highest reduction in the dry weight of monocot and dicots was noticed under two hand weeding (2.06 and 4.38 g/m^2) over the control (28.68 and 146.42 g/m^2), which recorded highest value (**Table 2**). Among the herbicidal treatments, mixed application of sulfosulfuron + metsulfuron curtailed the dry weight of monocot and dicot weeds to 92.12 and 95.97%, respectively followed by mesosulfuron + iodosulfuron (90.37 and 95.57%) and proved significantly superior over rest of the herbicidal treatments. The combined application of these herbicides furnished superior results as compare to application of single herbicide. Application of pendimethalin followed by different post-emergence herbicides also provided satisfactory result in curbing density and dry weight of weeds.

Weed control index (WCI)

Data confirm that the herbicide mixtures and sequential application attributed to higher weed control index than singly applied herbicides due to stunted weed growth and their dry biomass. The array of weed control index at 60 DAS was between 7.2 to 97.8% for monocot and dicot weeds (**Table 2**). Among the treatments, two hand weeding brought about greatest reduction in pooled dry matter accumulation of monocot, dicot and total weeds (92.8, 97.0 and 96.3%). However, variations were at par with sulfosulfuron + metsulfuron (92.2, 95.9 and 95.4%), mesosulfuron + iodosulfuron (90.4, 95.6 and 94.7%), clodinafop + metsulfuron (90.2, 95.3 and 94.4%) and pinoxaden + metsulfuron (89.7, 95.0 and 94.2%), respectively for dry biomass of monocot, dicot and total weeds. The performances of sole applied herbicides were not up to the satisfactory level. The solitary application of pendimethalin lagged behind herbicide mixtures and sequential application and hence leads to lesser WCI among all the treatments. However, the results were significant over the unweeded control, which accounted for the minimum weed control index among all weed control measures.

Effect on yield attributes and economics

All the treatment significantly improved the yield attributes that ascribed to augmented grain yield and

Table 1. Effect of weed control treatments on density of weeds at 60 DAS of wheat (pooled data of two year)

Treatment	Weed density (no/m²)						
	Melilotus indica	*Fumaria parviflora*	*Cheno-podium murale*	*Cheno-podium album*	*Convol-vulus arvensis*	Others dicotyledons weeds	*Phalaris minor*
Pendimethalin (750 g/ha) PE	6.24(38.4)	4.25(17.6)	3.42(11.2)	3.35(10.7)	2.77(7.2)	3.84(14.3)	5.97(35.1)
Sulfosulfuron (25 g/ha) PoE	4.67(21.3)	3.03(8.7)	1.98(3.4)	2.48(5.7)	1.65(2.2)	2.60(6.2)	4.38(18.7)
Metribuzin (210 g/ha) PoE	4.42(19.0)	2.95(8.2)	1.85(2.9)	2.46(5.6)	1.61(2.1)	2.49(5.7)	4.10(16.3)
Clodinafop (60 g/ha) PoE	4.36(18.5)	2.89(7.9)	1.81(2.8)	2.39(5.2)	1.59(2.0)	2.44(5.5)	4.16(16.8)
Metsulfuron (4 g/ha) PoE	4.17(16.9)	2.82(7.4)	1.62(2.1)	2.07(3.8)	1.57(2.0)	2.19(4.3)	3.82(14.1)
Pendimethalin + metribuzin (750 + 175 g/ha) PE	3.91(14.8)	2.75(7.1)	1.62(2.1)	2.02(3.6)	1.52(1.8)	2.17(4.2)	3.72(13.3)
Pendimethalin *fb* sulfosulfuron (750 + 20 g/ha) PE *fb* PoE	3.89(14.6)	2.67(6.6)	1.61(2.1)	1.98(3.4)	1.48(1.7)	1.91(3.1)	3.45(11.4)
Pendimethalin *fb* clodinafop (750 + 50 g/ha) PE *fb* PoE	3.41(11.1)	2.58(6.1)	1.51(1.8)	1.98(3.4)	1.40(1.5)	1.89(3.1)	3.14(9.4)
Pendimethalin *fb* metsulfuron (750 + 4 g/ha) PE *fb* PoE	3.10(9.1)	2.53(5.9)	1.46(1.6)	1.93(3.2)	1.32(1.2)	1.84(2.9)	3.10(9.1)
Sulfosulfuron + metsulfuron (30 + 2 g/ha) PoE	2.56(6.0)	2.17(4.2)	1.23(1.0)	1.67(2.3)	1.16(0.8)	1.74(2.5)	2.62(6.3)
Pinoxaden + metsulfuron (60 + 4 g/ha) PoE	2.78(7.2)	2.37(5.1)	1.36(1.4)	1.87(3.0)	1.26(1.1)	1.83(2.8)	3.05(8.8)
Mesosulfuron + iodosulfuron (12 + 2.4 g/ha) PoE	2.68(6.7)	2.25(4.6)	1.26(1.1)	1.82(2.8)	1.21(1.0)	1.78(2.7)	2.83(7.5)
Clodinafop + metsulfuron (60 +4 g/ha) PoE	2.76(7.1)	2.36(5.1)	1.32(1.2)	1.85(2.9)	1.23(1.0)	1.79(2.7)	2.89(7.8)
Two hand weeding at 30 and 45 DAS	2.22(4.4)	2.04(3.7)	1.17(0.9)	1.51(1.8)	1.13(0.8)	1.68(2.3)	2.38(5.2)
Unweeded control	9.74(94.3)	5.66(31.5)	3.63(12.7)	4.48(19.5)	3.14(9.3)	5.01(24.6)	6.53(42.1)
LSD (p=0.05)	2.28	1.11	0.90	0.88	0.69	1.14	1.43

*Data subjected to $\sqrt{X+0.5}$ transformation and figures in parentheses are original weed count/m²

Table 2. Effect of weed control treatments on weed dry weight and weed control index at 60 DAS of wheat (pooled data of two year)

Treatment	Weed dry matter accumulation (g/m²)			Weed control index (%)		
	Monocot weeds	Dicot weeds	Total weeds	Monocot weeds	Dicot weeds	Total weeds
Pendimethalin (750 g/ha) PE	5.18 (26.34)	7.95 (62.76)	9.47 (89.10)	9.2	57.5	49.4
Sulfosulfuron (25 g/ha) PoE	3.14 (9.38)	4.48 (19.58)	5.43 (28.96)	68.4	86.6	83.4
Metribuzin (210 g/ha) PoE	3.01 (8.58)	4.25 (17.54)	5.16 (26.12)	71.4	88.0	85.1
Clodinafop (60 g/ha) PoE	3.02 (8.63)	4.15 (16.76)	5.09 (25.39)	71.2	88.5	85.5
Metsulfuron (4 g/ha) PoE	2.95 (8.18)	4.14 (16.68)	5.04 (24.86)	72.9	88.6	85.8
Pendimethalin + metribuzin (750 + 175 g/ha) PE	4.09 (16.23)	6.61 (43.24)	7.74 (59.47)	43.8	70.5	66.0
Pendimethalin *fb* sulfosulfuron (750 + 20 g/ha) PE *fb* PoE	2.08 (3.84)	3.80 (13.96)	4.28 (17.80)	88.6	90.5	89.8
Pendimethalin *fb* clodinafop (750 + 50 g/ha) PE *fb* PoE	2.00 (3.52)	3.64 (12.78)	4.10 (16.30)	89.7	91.3	90.7
Pendimethalin *fb* metsulfuron (750 + 4 g/ha) PE *fb* PoE	1.98 (3.48)	3.48 (11.62)	3.95 (15.10)	89.9	92.1	91.4
Sulfosulfuron + metsulfuron (30 + 2 g/ha) PoE	1.64 (2.24)	2.52 (5.89)	2.94 (8.13)	94.4	96.0	95.4
Pinoxaden + metsulfuron (60 + 4 g/ha) PoE	1.85 (2.96)	2.78 (7.24)	3.27 (10.20)	91.7	95.1	94.2
Mesosulfuron + iodosulfuron (12 + 2.4 g/ha) PoE	1.79 (2.76)	2.64 (6.48)	3.12 (9.24)	92.5	95.6	94.7
Clodinafop + metsulfuron (60 +4 g/ha) PoE	1.82 (2.82)	2.73 (6.94)	3.20 (9.76)	92.3	95.3	94.4
Two hand weeding at 30 and 45 DAS	1.58 (2.06)	2.21 (4.38)	2.63 (6.44)	95.0	97.0	96.3
Unweeded control	5.40 (28.68)	12.12 (146.42)	13.25 (175.10)	0.0	0.0	0.0
LSD (p=0.05)	4.46	6.78	5.79	-	-	-

*Data subjected to $\sqrt{X+0.5}$ transformation and figures in parentheses are original weed count/m²

Table 3. Effect of weed control treatments on yield attributes and economics of wheat (pooled data of two year)

Treatment	Tillers/m row length)	Grains /spike (no.)	1000-grains weight	Grain yield (t/ha) 2015-16	2016-17	Pooled	Net returns (x10³₹/ha)	B:C
Pendimethalin (750 g/ha) PE	78.0	35.4	36.9	3.52	3.80	3.66	49.17	1.84
Sulfosulfuron (25 g/ha) PoE	83.1	37.4	37.6	3.71	3.99	3.85	52.35	1.92
Metribuzin (210 g/ha) PoE	82.1	37.6	37.8	3.69	3.97	3.83	52.65	1.97
Clodinafop (60 g/ha) PoE	85.1	38.2	38.5	3.72	4.00	3.86	53.19	1.97
Metsulfuron (4 g/ha) PoE	85.8	39.5	38.5	3.76	4.04	3.90	54.19	2.03
Pendimethalin + metribuzin (750 + 175 g/ha) PE	82.2	36.7	37.3	3.67	3.95	3.81	52.26	1.95
Pendimethalin *fb* sulfosulfuron (750 + 20 g/ha) PE *fb* PoE	88.0	40.7	39.2	3.83	4.05	4.04	56.57	2.10
Pendimethalin *fb* clodinafop (750 + 50 g/ha) PE *fb* PoE	88.5	41.4	40.0	3.84	4.11	3.98	55.46	2.05
Pendimethalin *fb* metsulfuron (750 + 4 g/ha) PE *fb* PoE	89.5	41.7	42.1	3.85	4.15	4.02	56.25	2.07
Sulfosulfuron + metsulfuron (30 + 2 g/ha) PoE	94.0	44.8	44.1	4.27	4.55	4.41	63.83	2.34
Pinoxaden + metsulfuron (60 + 4 g/ha) PoE	91.4	42.3	43.3	4.14	4.42	4.28	61.45	2.27
Mesosulfuron + iodosulfuron (12 + 2.4 g/ha) PoE	93.3	44.3	44.0	4.24	4.52	4.38	63.23	2.32
Clodinafop + metsulfuron (60 + 4 g/ha) PoE	92.1	43.2	43.8	4.18	4.46	4.32	61.53	2.21
Two hand weeding at 30 and 45 DAS	95.6	45.4	44.4	4.36	4.64	4.50	59.58	1.79
Unweeded control	73.5	32.7	36.5	3.14	3.42	3.28	42.81	1.62
LSD (p=0.05)	6.6	4.0	3.1	0.40	0.38	0.39	3.97	0.22

economics over the unweeded control (**Table 3**). The highest number of tillers per meter row length, grains per spike and 1000-grains weight were through the ready-mix application of metsulfuron + sulfosulfuron (94.0, 44.8 and 44.1) followed by mesosulfuron + iodosulfuron (93.3, 44.3 and 44.0) which is at par with two hand weeding (95.6, 45.4 and 44.4) that attributed to enhanced grain yield. The maximum yield increase was recorded under two hand weeding (37.0% higher) with respect to control. Further, the grain yield data elucidated that combined application of herbicides either as pre-mix, tank-mix or sequentially performed better in obtaining higher yield of wheat over their sole application or applied singly. Among the herbicidal treatments, the mixed application of metsulfuron + sulfosulfuron and mesosulfuron + iodosulfuron provided 34.3 and 20.5% yield augmentation compared to unweeded control. The solitary application of any of the herbicide resulted lesser yield. The similar trend of results was also recorded for net returns and B-C ratio. The highest net returns was realized by applying metsulfuron + sulfosulfuron and mesosulfuron + iodosulfuron (49.1 and 47.7% more) with B-C ratio of 2.34 and 2.32 over unweeded control (1.62).

Hand weeding (30 and 45 DAS) obtained the highest density for all the weeds due to their complete and effective removal whereas, sulfosulfuron + metsulfuron found more superior among the herbicidal treatments in curtailing the weed growth and their population over the unweeded control. The tank mixtures of broad-leaf (e.g. metsulfuron, carfentrazone) and grassy weed (e.g. clodinafop, pinoxaden) killing herbicides provided higher order of performance in terms of weed density and intensity of total weeds (Meena *et al.* 2017a). The application of tank-mixtures (sulfosulfuron + metsulfuron) provided better broad spectrum (both monocot and dicot) weed control. This combination exhibit properties of both foliar and soil activity that inhibits cell division in shoots and roots and growth by inhibiting plant enzyme acetolactase synthase, thereby, blocking branches chain of amino acid biosynthesis and hence the plant suffers. Due to this, phloem transport of the plant is hampered. A secondary effect is stunted growth on account of cessation of cell division and slow plant death. Contrary to the alone application of either of the herbicide was not found effective to control all sort of the weeds in the entire crop season (Lekh Chand and Puniya 2017, Chaudhari *et al.* 2017, Meena *et al.* 2017a, b). Tank-mix application of broad-leaf weeds and grass suppressing herbicides over their individual applications in reducing total weed density and dry matter gave better results (Singh *et al.* 2017, Barla *et al.* 2017, Meena *et al.* 2019). Application of mesosulfuron + iodosulfuron inhibits the acetohydroxy acid synthesis enzyme in the plants, which is responsible for the synthesis of the branched chain amino acids valine, leucine, and isoleucine and cell division in the growing tips of roots and shoots. Further, its secondary effect on photosynthesis, respiration and ethylene production produce the symptoms of yellowing and reddening of monocot and leaf dropping in dicot weeds. Sole application of a single herbicide was less effective in controlling weeds as compared to their ready-mix application, but metsulfuron had significant effects on population of broad-leaf weeds as compared to other single herbicide (Meena *et al.* 2019). The superiority of tank mix application of broad-leaf weed and grass suppressing herbicides over their individual applications in curtailing total weed density and dry matter has also been reported by other authors (Singh *et al*. 2017, Barla *et al*. 2017).

From the results, it was concluded that the tank-mixtures application of sulfosulfuron + metsulfuron (32 g/ha), mesosulfuron + iodosulfuron (14.4 g/ha) as post-emergence at 5 WAS provided better broad-spectrum weed control. Both the herbicide combinations have higher compatibility in mixtures and hence their higher compatibility and synergistic effects led to better broad-spectrum weed control that attributed to higher grain yield, net returns and B-C ratio.

REFERENCES

Barla S, Upasani RR, Puran AN. 2017. Herbicide combinations for control of complex weed flora in wheat. *Indian Journal of Weed Science* **49**: 36–40.

Chaudhari DD, Patel VJ, Patel HK, Mishra A, Patel BD, Patel RB. 2017. Assessment of pre-mix broad spectrum herbicides for weed management in wheat. *Indian Journal of Weed Science* **49**: 33–35.

Chhokar RS, Sharma RK, Sharma I. 2012. Weed management strategies in wheat-A review. *Journal of Wheat Research* **4**: 1–21.

Das KT, Yaduraju NT. 2012. The effects of combining modified sowing methods with herbicide mixtures on weed interference in wheat. *International Journal of Pest Management* **58**: 311–20.

Fahad S, Hussain S, Saud S, Hassan S, Muhammad H, Shan D, et al. 2014. Consequences of narrow crop row spacing and delayed *Echinochloa colona* and *Trianthema portulacastrum* emergence for weed growth and crop yield loss in maize. *Weed Research* **54**: 475–483.

Lekh Chand, Puniya R. 2017. Bio-efficacy of alone and mixture of herbicides against complex weed flora in wheat (*Triticum aestivum* L.) under sub-tropical conditions. *Indian Journal of Agricultural Science* **87**: 1149–1154.

Meena V, Kaushik MK, Dotaniya ML, Meena BP and Das H. 2019. Bio-efficacy of readi-mix herbicides on weeds and productivity in late-sown wheat. *Indian Journal of Weed Science* **51**(4): 344–351.

Meena VD, Kaushik MK, Meena SK, Bhimwal JP. 2017b. Influence of pre- and post-emergence herbicide application on weed growth and nutrient removal in wheat (*Triticum aestivum* L.). *Journal of Pharmacognosy and Phytochemistry* **6**: 2413–2418.

Meena VD, Kaushik MK, Verma A, Upadhayay B, Meena SK, Bhimwal JP. 2017a. Effect of herbicide and their combinations on growth and productivity of wheat (*Triticum aestivum* L.) under late sown condition. *International Journal of Chemical Studies* **5**: 1512–1516.

Sharma N, Thakur N, Chopra P, Kumar S, Badiyala D. 2015. Evaluation of metsulfuron methyl and clodinafop alone and in combination with other herbicides against weeds in wheat (*Triticum aestivum* L.).*Research on Crops* **16**: 447–455.

Singh VP, Barman KK, Singh PK, Singh R, Dixit A. 2017. Managing weeds in rice (*Oryza sativa*)-wheat (*Triticum aestivum*L.)-greengram (*Vigna radiata*) system under conservation agriculture in black cotton soils. *Indian Journal of Agricultural Sciences* **87**: 739–45.

Susha VS, Das TK, Sharma AR, Nath CP. 2014. Carryover effect of weed management practices of maize (*Zea mays*) on weed dynamics and productivity of succeeding zero and conventional till wheat (*Triticum aestivum* L.). *Indian Journal of Agronomy* **59**: 41–47.

Verma SK, Singh SB, Meena RN, Prasad SK, Meena RS, Gaurav. 2015. A review of weed management in India: the need of new directions for sustainable agriculture. *The Bioscan* **10**: 253–263.

Zimdahl RL. 2013. *Fundamentals of Weed Science* (4th edition), Academic Press, Elsevier, London. pp. 130–143.

Indian Journal of Weed Science **52**(3): 237–240, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Management of herbicide resistant *Phalaris minor* in wheat

S.S. Punia*, Jitender Soni, Manjeet, Sushil Kumar Singh and Paras Kamboj

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

**Email: Puniasatbir@gmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00045.3

Type of article: Research article

Received : 2 March 2020

Revised : 13 August 2020

Accepted : 18 August 2020

Key words

Herbicide mixture

pendimethalin

Phalaris minor

pinoxaden

pyroxasulfone

wheat, cross resistance

ABSTRACT

Field experiment was conducted at CCS Haryana Agricultural University during *Rabi* 206-17 and 2017-18 to evaluate bio-efficacy of different herbicides and their combination against cross resistant *P. minor* in wheat, and to study the phytotoxic effects on the crop, if any. The treatments included application pre-emergence herbicides pendimethalin 1500 g/ha and its mixture with metribuzin 175 g/ha alone, pendimethalin + pyroxasulfone Tank mix (TM) at 1500 + 102 g/ha alone and their sequential application with post-emergence herbicides application (PoE) of mesosulfuron + iodosulfuron ready mix (RM) 14.4 g/ha and pinoxaden 60 g/ha along with weedy check treatment. The minimum density of *P. minor,* weed biomass and the highest wheat grain yield was observed with pendimethalin + pyroxasulfone TM *fb* mesosulfuron+ iodosulfuron RM (1500 + 102 *fb* 14.4 g/ha). All the herbicides significantly reduced the weed biomass as compared with the control but maximum reduction in the weed biomass was achieved with pendimethalin + pyroxasulfone TM *fb* mesosulfuron+ iodosulfuron RM. Pinoxaden at 60 g/ha did not control *Rumex dentatus* and *Chenopodium album.* Only pre-emergence application of metribuzin, pendimethalin + metribuzin (before sowing), pinoxaden + metribuzin TM caused toxicity of up to 5% at 10 days after treatment (DAT). The wheat recovered from toxicity by 20 DAT without any yield penalty. On-farm demonstrations of pyroxasulfone at 127.5 g/ha PE in Haryana revealed 88.3 % control of multiple herbicide resistant *P. minor.* Its integration with pendimethalin at 1.5 kg/ha (PE) and post-emergence herbicides at 35 DAS has improved control of *P. minor* to 92.1%.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the second most important food grain of India with an area of 29.6 million ha, a production of 99.8 million tones, and an average productivity of 3.37 t/ha (Anonymous 2018-19). Haryana is the major wheat growing state in India with an area, production and productivity of 2.5 million ha, 11.5 million tons, and 4.51 t/ha, respectively (Anonymous 2016-17). *Phalaris minor* Retz. (little seed canarygrass) is the dominant and troublesome grass weed of wheat in rice-wheat cropping system in the north-western Indo-Gangetic Plains of India. Evolution of resistance in *P. minor* against isoproturon in the early 1990s was considered as one of the most serious cases of herbicide resistance in the world resulting in total crop failure under heavy infestation. The GR_{50} (dose of a herbicide required to cause 50% growth reduction) of isoproturon in resistant biotypes of *P. minor* from different parts of Haryana was reported to increase by 2-11 times as compared to its susceptible populations (Yadav *et al.* 1996, Malik and Yadav 1997, Chhokar and Malik 2002). Therefore, the existing recommendation of isoproturon against *P. minor* was replaced by four new herbicides (clodinafop, sulfosulfuron, fenoxaprop) in resistance affected areas. Clodinafop 60 g/ha, fenoxaprop 120 g/ha, sulfosulfuron 25 g/ha applied at three leaf stage reduced the dry weight of resistant and susceptible biotypes by 82-95% (Yadav *et al.* 2004, Yadav and Malik 2005). Complaints of poor efficacy of these alternate herbicides started appearing at farmers' fields after their continuous use. Even the repeated application of these herbicides or their application at higher doses failed to provide satisfactory control of resistant population of *P. minor*.

Pyroxasulfone is a new pre-emergence herbicide that provides effective control of *P. minor* including populations with evolved resistance to multiple herbicide modes of action (Busi *et al.* 2012). Pyroxasulfone inhibits multiple steps in the elongation of very-long-chain fatty acids (VLCFA) in susceptible seedlings, with excellent selectivity in several crops such as wheat, maize and soybean (Tanetani *et al.* 2009) The present study was conducted with the objectives of evaluating the efficacy of different herbicide mixtures and their sequential application for control of resistant *P. minor* in wheat and to study the phytotoxic effects on the crop, if any.

MATERIALS AND METHODS

A field experiment was conducted during *Rabi* 2016-17 and 2017-18 at CCS HAU Hisar which is isituated at a iheight of iabout 215.2 m above mean sea level with latitude iof 29º10' in the North and longitude of 75º46' in ithe East iin ithe subtropical zone. The soil of the experimental field was sandy loam in texture, low in available N, medium in P and high in K with slightly alkaline in reaction (pH 8.2). The treatments included pre-emergence (PE) application of pendimethalin 1500 g/ha and mixture with metribuzin 175 g/ha alone, pendimethalin + pyroxasulfone (TM) at 1500 + 102 g/ha alone and their sequential post-emergence herbicides application (PoE) of mesosulfuron + iodosulfuron (RM) 14.4 g/ha and pinoxaden 60 g/ha. Herbicides were applied using 375 L/ha through knapsack sprayer fitted with flat-fan nozzle. The experiment was laid out in a randomized block design. Wheat cultivar '*HD 2967*' was sown on November 12th and November 19th, during 2016 and 2017, respectively at a row spacing of 20 cm using seed rate of 100 kg/ha. The weed density (m^2) was recorded at 30 and 60 days after treatment (DAT) during both the years. From each plot, one square meter area was selected at random for recording number of tillers, weed density and grain yield. Phyto-toxicity in terms of chlorosis, stunting, leaf burning and epinasty was recorded at 10 and 20 DAT. Data collected was analyzed statistically using analysis of variance and least significantly difference (LSD) at 5% probability level to compare treatment means.

The efficacy of pyroxasulfone 127.5 g/ha was assessed at farmers' fields too. Seven demonstrations were organized in rice-wheat growing areas of state, and it was compared with pre-emergence application of pendimethalin 1.5 kg/ha and recommended post-emergence herbicides during *Rabi* 2017-18.

RESULTS AND DISCUSSION

The major species identified in the experimental field were *Phalaris minor, Rumex dentatus* and *Chenopodium album* during both the years.

The weed density was significantly affected by different pre- and post-emergence herbicides. The minimum *P. minor* density (**Table 1**), weed biomass and higher weed control efficiency (**Table 2**) at 30 DAT and 60 DAT was recorded during both the years with pendimethalin + pyroxasulfone (TM) *fb* mesosulfuron + iodosulfuron (RM) (1500+102 *fb* 14.4 g/ha).

Table 1. Effect of different treatments on weeds density (no./m^2) in wheat (2016-17 and 2017-18)

Treatment	*P. minor*				*Rumex dentatus*				*Chenopodium album*			
	2016		2017		2016		2017		2016		2017	
	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT
Pendimethalin (1500 g/ha) PE	5.9 (33.4)	9.5 (90.0)	5.6 (31.3)	9.4 (86.7)	1.0 (0)	1 (0)	1.4 (1.0)	1.0 (0)	1.8 (2.4)	1.3 (0.7)	1.6 (2.0)	1.2 (0.6)
Metribuzin (210 g/ha) PE	5.6 (30.2)	9.5 (88.4)	5.4 (28.7)	9.3 (86.0)	1.2 (0.4)	1.1 (0.3)	1.1 (0.3)	1.0 (0)	1.7 (1.8)	1.3 (0.7)	1.6 (2.0)	1.2 (0.6)
Pendimethalin + metribuzin (1500+175 g/ha) PE	4.2 (16.3)	9.1 (81.4)	4.2 (17.0)	8.6 (78.7)	1.4 (1.0)	1.0 (0)	1.0 (0)	1.1 (0.3)	1.0 (0)	1 (0)	1.0 (0)	1.0 (0)
Pendimethalin + metribuzin *fb* pinoxaden (1000 + 175 *fb* 60 g/ha) PE *fb* PoE	4.6 (20.4)	8.4 (70.2)	4.4 (19.3)	8.3 (68.7)	1.0 (0)	1.1 (0.3)	1.0 (0)	1.0 (0)	1.5 (1.4)	1.0 (0)	1.5 (1.3)	1.0 (0)
Pendimethalin + metribuzin *fb* mesosulfuron + iodosulfuron (1000 + 175 *fb* 14.4 g/ha) PE *fb* PoE	4.2 (16.4)	7.8 (59.6)	4.0 (15.3)	7.5 (57.3)	1.1 (0.3)	1.0 (0)	1.0 (0)	1.0 (0)	1.4 (1.0)	1.0 (0)	1.0 (0)	1.0 (0)
Pendimethalin + pyroxasulfone (1500+102 g/ha) PE	3.1 (8.4)	5.2 (25.8)	2.6 (7.3)	5.1 (26.7)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.1 (0.3)	1.1 (0.4)	1.1 (0.3)	1.1 (0.3)
Pendimethalin + pyroxasulfone *fb* pinoxaden (1500+102 *fb* 60 g/ha) PE *fb* PoE	2.6 (5.6)	4.8 (22.2)	2.2 (4.3)	4.5 (20.0)	1.1 (0.3)	1.1 (0.3)	1.0 (0)	1.0 (0)	1.4 (1.0)	1.0 (0)	1.3 (1.0)	1.0 (0)
Pendimethalin + pyroxasulfone *fb* mesosulfuron+ iodosulfuron (1500+102 *fb* 14.4 g/ha) PE *fb* PoE	2.3 (4.4)	4.7 (21.7)	2.2 (4.3)	4.6 (20.0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.2 (0.4)	1.0 (0.2)	1.1 (0.3)	1.0 (0)
Pendimethalin + metribuzin *fb* pinoxaden (1500+175 *fb* 60 g/ha) before sowing *fb* PoE	5.2 (26.4)	8.3 (67.8)	5.0 (24.3)	7.3 (66.7)	1.1 (0.3)	1.1 (0.3)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)
Sulfosulfuron *fb* pinoxaden (25 *fb* 60 g/ha) BI *fb* PoE	5.5 (29.9)	11.3 (121.7)	5.4 (28.7)	10.9 (118.7)	1.9 (2.7)	1.7 (1.7)	1.9 (3.0)	1.0 (0)	1.4 (1.0)	1.0 (0)	1.5 (1.3)	1.0 (0)
Pinoxaden (60 g/ha) PoE	4.8 (22.3)	11.4 (128.4)	4.5 (21.0)	11.2 (126.7)	2.7 (6.4)	1.9 (2.7)	2.4 (5.0)	1.5 (1.3)	2.9 (7.3)	1.5 (1.4)	2.9 (8.3)	1.7 (2.0)
Pinoxaden + metribuzin (50+120 g/ha) PoE	4.4 (18.4)	9.4 (88.2)	4.5 (19.7)	9.3 (86.6)	1.1 (0.3)	1.2 (0.4)	1.1 (0.3)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)
Pinoxaden + metribuzin (50+150 g/ha) PoE	3.9 (14.3)	8.5 (71.6)	3.9 (15.7)	8.5 (72.0)	1.2 (1.4)	1.6 (1.7)	1.1 (0.3)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)
Mesosulfuron + iodosulfuron (14.4 g/ha) PoE	4.6 (20.6)	9.1 (80.2)	4.6 (22.3)	9.1 (82.6)	1.1 (0.3)	1.0 (0)	1.1 (0.3)	1.1 (0.3)	1.1 (0.3)	1.1 (0.3)	1.0 (0)	1.0 (0)
Weedy check	6.5 (41.4)	12.4 (154.4)	6.2 (38.3)	12.5 (157.3)	2.8 (7.2)	1.2 (0.5)	2.4 (6.0)	1.1 (0.3)	3.1 (8.4)	1.6 (2.5)	3.5 (12)	1.4 (1.3)
Weed free	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)
LSD (p=0.05)	1.5	2.7	1.8	3.1	0.7	0.2	0.7	0.2	0.72	0.4	0.7	0.4

Pre-emergence application of pendimethalin + pyroxasulfone (RM) at 1500 + 102 g/ha either alone or followed by sequential use of pinoxaden 60 g/ha , meso + iodosulfuron (RM) 14.4 g/ha at 35 DAS caused significant reduction in density *P. minor* and provided 83-93% control of *P. minor* as reported earlier (Punia *et al.* 2018)

Above treatment also showed significant result for the control of broad leaf weed such as *Rumex dentatus* and *Chenopodium album*. *Rumex dentatus* was fully controlled with the application of this treatment. These results were in conformity with Singh *et al.* (2011) who reported that tank mix application of metsulfuron + carfentrazone provided 92% control over broad-leaf weeds. Pinoxaden at 60 g/ha did not provide any control of *R. dentatus* and *C. album* and this was in line with the finding of Singh *et al.* (2011). There was significant increase in number of tillers/ m^2 and wheat grain yield with pendimethalin + pyroxasulfone (TM) *fb* mesosulfuron +

Table 2. Effect of different treatments on weed biomass and weed control efficiency in wheat (2016-17 and 2017-18)

Treatment	Weed biomass (g/m^2)				Weed control efficiency (%)			
	2016		2017		2016		2017	
	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT
Pendimethalin (1500 g/ha) PE	4.3(17.4)	20.2(410.4)	4.12 (16.1)	19.4 (401.6)	49.7	47.69	56.3	49.6
Metribuzin (210 g/ha) PE	4.3(18.2)	20.6(424.1)	4.64 (20.6)	20.36(418.7)	47.3	45.9	43.9	47.4
Pendimethalin + metribuzin (1500+175 g/ha) PE	4.4(18.4)	19.0(360.2)	3.94(14.8)	19.2(372.9)	46.9	54.0	59.7	53.2
Pendimethalin + metribuzin *fb* pinoxaden (1000 + 175 *fb* 60 g/ha) PE *fb* PoE	4.2(16.6)	18.4(340.7)	3.64(12.2)	18.1(328.7)	51.9	56.5	66.7	52.4
Pendimethalin + metribuzin *fb* mesosulfuron + iodosulfuron (1000 + 175 *fb* 14.4 g/ha) PE *fb* PoE	3.2(9.6)	16.15(260.1)	3.37(10.4)	15.8(257.0)	72.3	66.8	71.7	67.4
Pendimethalin + pyroxasulfone (1500+102 g/ha) PE	2.7(6.4)	10.06(100.2)	2.48(5.9)	9.9 (98.8)	81.5	87.2	83.8	87.6
Pendimethalin + pyroxasulfone *fb* pinoxaden (1500+102 *fb* 60 g/ha) PE *fb* PoE	2.5(5.4)	9.8(96.3)	2.35(4.5)	9.5 (89.6)	84.4	87.7	87.5	88.7
Pendimethalin + pyroxasulfone *fb* mesosulfuron+ iodosulfuron (1500+102 *fb* 14.4 g/ha) PE *fb* PoE	2.2(3.8)	9.9(97.3)	1.70 (2.3)	9.5 (94.6)	89.0	87.5	93.5	88.1
Pendimethalin + metribuzin *fb* pinoxaden (1500+175 *fb* 60 g/ha) before sowing *fb* PoE	4.4(18.6)	21.9(481.1)	4.25(17.1)	21.8(476.8)	46.3	38.6	53.5	40.1
Sulfosulfuron *fb* pinoxaden (25 *fb* 60 g/ha) BI *fb* PoE	4.4(18.6)	22.2(493.4)	4.34(17.9)	22.3(498.2)	46.2	37.0	51.3	28.6
Pinoxaden (60 g/ha) PoE	4.1(16.8)	19.7(390.1)	3.89(14.2)	19.6(383.8)	53.5	50.2	61.3	51.7
Pinoxaden + metribuzin (50+120 g/ha) PoE	3.7(13.3)	18.7(352.1)	3.63(12.2)	18.5(349.2)	61.5	55.0	66.7	56.2
Pinoxaden + metribuzin (50+150 g/ha) PoE	3.5(11.6)	18.2(331.1)	3.37(10.4)	17.9(329.1)	66.5	57.7	71.7	58.7
Mesosulfuron + iodosulfuron (14.4 g/ha) PoE	3.8(13.5)	19.7(390.2)	3.91(14.3)	19.6(384.5)	61.0	50.2	61.0	51.7
Weedy check	6.0(34.6)	28.0(784.2)	6.10(36.7)	28.2(797.1)	0	0	0	0
Weed free	1.0(0)	1.0(0)	1.0(0)	1(0)	100	100	100	100
LSD (p=0.05)			1.1	5.5				

Table 3. Effect of different treatments on crop phytotoxicity, no. of tillers and grain yield of wheat (2016-17 and 2017-18)

Treatment	Crop phytotoxicity (%)				No. of tillers/ m^2		Grain yield (t/ha)	
	2016		2017		2016	2017		
	10 DAT	20 DAT	10 DAT	20 DAT	Harvest		2016	2017
Pendimethalin (1500 g/ha) PE	0	0	0	0	390	396	5.56	4.86
Metribuzin (210 g/ha) PE	5	0	0	0	398	396	4.63	4.80
Pendimethalin + metribuzin (1500+175 g/ha) PE	0	0	0	0	410	404	5.51	5.06
Pendimethalin + metribuzin *fb* pinoxaden (1000 + 175 *fb* 60 g/ha) PE *fb* PoE	0	0	0	0	404	407	6.08	5.10
Pendimethalin + metribuzin *fb* mesosulfuron + iodosulfuron (1000 + 175 *fb* 14.4 g/ha) PE *fb* PoE	0	0	0	0	402	410	6.16	5.41
Pendimethalin + pyroxasulfone (1500+102 g/ha) PE	0	0	0	0	436	438	5.09	5.80
Pendimethalin + pyroxasulfone *fb* pinoxaden (1500+102 *fb* 60 g/ha) PE *fb* PoE	0	0	0	0	438	439	6.16	5.80
Pendimethalin + pyroxasulfone *fb* mesosulfuron+ iodosulfuron (1500+102 *fb* 14.4 g/ha) PE *fb* PoE	0	0	0	0	439	441	6.28	5.82
Pendimethalin + metribuzin *fb* pinoxaden (1500+175 *fb* 60 g/ha) before sowing *fb* PoE	5	5	5	5	371	386	5.99	4.42
Sulfosulfuron *fb* pinoxaden (25 *fb* 60 g/ha) BI *fb* PoE	0	0	0	0	388	399	6.11	5.00
Pinoxaden (60 g/ha) PoE	0	0	0	0	382	396	5.11	4.80
Pinoxaden + metribuzin (50+120 g/ha) PoE	5	0	5	0	390	400	5.02	5.00
Pinoxaden + metribuzin (50+150 g/ha) PoE	5	0	5	0	404	401	5.23	5.05
Mesosulfuron + iodosulfuron (14.4 g/ha) PoE	0	0	0	0	400	401	5.90	4.92
Weedy check	0	0	0	0	376	370	4.17	3.64
Weed free	0	0	0	0	442	435	6.17	5.80
LSD (p=0.05)					27.9	28.1	0.14	0.13

Table 4. Efficacy of pyroxasulfone alone and in combination with other herbicides in wheat (2017-18)

Name and address of farmer	T_1	T_2	*P. minor* control (%)			Grain yield (t/ha)			T_9	T_{10}
			T_3	T_4	T_5	T_6	T_7	T_8		
Sudan Nain V. Kalwan Teh. Narwana (Jind)	90	90	90	70	60	5.40	5.45	5.40	5.10	5.00
Balraj s/o Hawa Singh, V. Kalwan Teh. Narwana (Jind)	85	90	90	60	55	5.28	5.30	5.34	5.10	4.90
Amarjeet Gill, V. Samain, Teh. Tohana (Fatehbad)	88	90	95	85	80	5.40	5.45	5.45	5.28	5.20
Satpal Singh, V. Samain. Teh. Tohana (Fatehbad)	90	95	95	75	75	5.46	5.50	5.50	5.20	5.25
Kala s/o Balraj Nain V. Kalwan Teh. Narwana (Jind)	85	90	90	65	60	5.58	5.50	5.60	5.22	5.18
Chanda Ram, V. Danoura (Ambala)	95	100	100	90	80	4.80	4.86	4.86	4.80	4.80
Prem Gujjar, V. Kheri Raiwali (Kaithal)	85	88	85	75	65	5.60	5.60	5.58	5.10	5.08
Mean	88	92	92	74	68	5.36	5.38	5.39	5.11	5.06

T_1- Pendimethalin + pyroxasulfone (1000 + 127.5 g/ha (PE); T_2- Pendimethalin + pyroxasulfone (1000 + 255 g/ha (PE) *fb* PoE herbicide; T_3- Pendimethalin + pyroxasulfone (1000 + 127.5 g/ha (PE *fb* PoE herbicide; T_4- Pendimethalin + metribuzin 1.5 kg/ha (PE) *fb* PoE herbicide; T_5- Pendimethalin 1500 g/ha *fb* PoE herbicide; T_6- Pendimethalin + pyroxasulfone (1000 + 127.5 g/ha (PE); T_7- Pendimethalin + pyroxasulfone (1000 + 255 g/ha (PE) *fb* PoE herbicide; T_8- Pendimethalin + pyroxasulfone (1000 + 127.5 g/ha (PE *fb* PoE herbicide; T_9- Pendimethalin + metribuzin 1.5 kg/ha (PE) *fb* PoE herbicide; T_{10}- Pendimethalin 1500 g/ha *fb* PoE herbicide

iodosulfuron (RM) (**Table 3**). The probable reason for the higher grain yield under this treatment may be due to lowest weed density resulting in no crop- weed competition and higher number of tillers. The other reason may be the lack of phytotoxicity to wheat with these herbicides. These findings were in concurrence with those of Malik *et al.* (1998) who reported that wheat grain yield enhances with the use of herbicides due to increase in weed control efficiency and number of tillers and thus grain weight.

On-farm evaluation of pyroxasulfone in wheat

The use of pre-emergence application of pyroxasulfone at 127.5 g/ha was demonstrated at 7 sites in rice–wheat growing areas of Haryana. It provided 88.3% control of multiple herbicide resistant *P. minor* whereas integration of this herbicide with pendimethalin at 1.5 kg/ha (PE) and post-mergence herbicides at 35 DAS improved control of *P. minor* to 92.1% with grain yield of 5.39 t/ha which was 6.54% higher than earlier recommended herbicide pendimethalin at 1.5 kg/ha (**Table 4**).

It may be concluded that pre-emergence of application of pyroxasulfone at 127.5 g/ha followed by post-emergence application of meso + iodosulfuron at 14.4 g/ha at 35 DAS provides effective control of multiple herbicides resistant *P. minor*, without any toxicity to wheat crop.

REFERENCES

Anonymous 2016-17, 2018-19. *Agricultural Statistics at a Glance,* Ministry of Agriculture and Farmer Welfare, Govt. of India.

Busi R, Gaines TA, Walsh MJ and Powles SB. 2012. Understanding the potential for resistance evolution to the new herbicide pyroxasulfone: field selection at high doses versus recurrent selection at low doses. *Weed Research* **52**: 489–499.

Chhokar RS, Malik RK. 2002. Isoproturon resistant littleseed canary grass *(Phalaris minor)* and its response to alternate herbicides. *Weed Technology* **16**, 116–123.

Gupta OP. 2004. *Modern Weed Management* (2nd Ed.). Agrobios Jodhpur, India. pp. 18–23.

Malik RK, Yadav A, Singh S and Malik YP. 1998. Development of resistance to herbicides in *P. minor* and mapping of variations in weed flora. pp.291–296. In: *Proceedings of International Conference on Wheat: Research needs beyond 2000 AD*, 12-14 August 1997, Karnal, India.

Malik RK and Yadav A. 1997. Potency of alternate herbicides against isoproturon resistant littleseed canary grass. pp. 208–210. In: *Proceedings of 16th Asia Pacific Weed Science Society Conference,* 8-12 Sep. 1997, Kuala Lumpur, Malaysia.

Marwat KB, Hussain Z, Saeed M Gul B and Noor S. 2005. Chemical weed management in wheat at higher altitudes. *Pakistan Journal of Weed Science Research* **11**: 102–107.

Punia SS, Singh SK and Singh S. 2018. Management of cross resistance in *P. minor* against recommended herbicides in wheat. pp. 54. In: *Proceedings of ISWS Golden Jubilee International Conference,* 21-24 November 2018, Jabalpur, India.

Singh S, Punia SS, Yadav A and Hooda VS. 2011. Evaluation of carfentrazone-ethyl + metsulfuron-methyl against broad-leaf weeds of wheat. *Indian Journal of Weed Science* **43**: 12–22.

Singh S, Singh K, Punia SS, Yadav A and Dhawan RS. 2011. Effect of stage of *Phalaris minor* on the efficacy of accord plus (fenoxaprop + metsulfuron, readymix). *Indian Journal of Weed Science* **43**: 23–31.

Tanetani Y, Kaku K, Kawai K, Fujioka T and Shimizu T. 2009. Action mechanism of a novel herbicide, pyroxasulfone. *Pesticide Biochemistry and Physiology* **95**: 47–55.

Yadav A, Balyan RS, Garg RS, Malik RK. 1996. Resistance against isoproturon in different biotypes of littleseed canary grass. pp. 34–35 In: *Test of Agrochemicals and Cultivars No.* 17 *(Annals of Applied Biology 128 Supplement)*.

Yadav A, Malik RK, Balyan RS, Banga RS, Mehta R, Bellinder RR. 2004. Effect of different herbicides alone and in mixture on the control of isoproturon resistant and susceptible populations of *Phalaris minor*. *Indian Journal of Weed Science* **36**: 1–4.

Yadav A, Malik RK. 2005. Herbicide Resistant *Phalaris minor* in Wheat - a Sustainability Issue. Resource Book. Department of Agronomy and Directorate of Extension Education, CCSHAU, Hisar, India, p. 152.

Indian Journal of Weed Science **52**(3): 241–244, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Indian Journal of Weed Science

Effect of nitrogen levels and weed control methods on yield and economics of wheat under zero-tillage conditions

Manoj Kumar*, Ram Pratap Singh[1], Deepak Pandey[1] and Gajendra Singh[1]

Krishi Vigyan Kendra,Ganiwan, Chitrakoot Utter Padesh210206, India

[1]Department of Agronomy, Narendra Deva University of Agricultural & Technology, Kumarganj, Ayodhya, Uttar Pradesh 224 229, India

**Email: manojbu123@gmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00046.5

Type of article: Research article

Received : 8 March 2020
Revised : 1 August 2020
Accepted : 3 August 2020

Key words
Herbicides
Nitrogen levels
Nitrogen uptake
Weed control
Weed management
Wheat

ABSTRACT

A field experiment was conducted during *Rabi* seasons of 2015-16 and 2016-17 to study the effect of nitrogen and weed control on wheat yield, nitrogen uptake and economics of wheat. The treatments comprised of 4 levels of nitrogen, *viz.* 90, 120, 150 and 180 kg/ha, and 5 weed control methods, *viz.* weedy check, hand weedings at 30 and 60 days after seeding (DAS), clodinafop + metsulfuron (60 + 4 g/ha), fenoxaprop + metsulfuron (120 + 4 g/ha) and sulfosulfuron + metsulfuron (25 + 4 g/ha). Weed density was reduced with increased rate of nitrogen from 90 to 180 kg/ha. Crop fertilized with180 kg N/ha was at par with 150 kg N/ha but produced significantly higher weeds biomass than the rest of the nitrogen levels. The uptake of nitrogen by weeds was significantly higher with 180 kg/ha than the other N-levels. Post-emergence spray of clodinafop + metsulfuron (60 + 4 g/ha) recorded significantly the lowest weed population followed by sulfosulfuron + metsulfuron (25 + 4 g/ha) and fenoxaprop + metsulfuron (120 + 4 g/ha). Hand weeding twice (30 and 60 DAS) recorded the significantly lowest weeds biomass, followed by clodinafop + metsulfuron (60 + 4 g/ha). Weedy check recorded significantly maximum amount of nitrogen uptake by weeds. Nitrogen applied at 180 kg/ha recorded the highest wheat grain yield (3.82 and 3.98 t/ha), crop nitrogen uptake (96.81 and 99.69 kg/ha), gross returns (₹ 73700/ha), net returns (₹ 49600/ha) and B:C ratio (2.06).

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the major staple foods of the world. In India, wheat is grown in an area of 29.58 mha with the total production of 99.70 mt and average productivity of 3.37 t/ha (DAC&FW 2018). The productivity of wheat in Eastern Uttar Pradesh is quite low (3.27 t/ha) as compared to Punjab (5.09 t/ha) and Haryana (4.41 t/ha) (DAC&FW 2018) due to the adoption of long duration rice varieties coupled with late harvesting resulted in delayed sowing of wheat. The field preparation also gets delayed due to high moisture after harvest of rice, which causes poor tilth of soil and creates hindrance in use of seed drill. Thus, to avoid delayed sowing of wheat, the farmers broadcast the seeds in soil which result in uneven distribution and improper depth of sowing in the field caused poor germination and reduced yield. Besides, repeated tillage generally disturbs soil physical properties and enhances air pollution due to higher combustion of fuel. Sowing of wheat by zero-till drill under untilled field advances the sowing by 10-15 days, and emergence of seedling by 8-9 days.

Weeds are one of the major constraints in wheat production as they reduce productivity of crop due to competition for light, space and nutrients, allelopathy effect and increase overhead costs (Dangwal *et al.* 2010). Weed causes 10- 65% yield reduction in wheat (Dangwal *et al.* 2010). Weed management at right time and optimum dose of nitrogen are most important factors which may affect the wheat productivity. Manual weeding is the most widely used practice of weed management. However, it is labour intensial, and costly. Besides, intra-row weeds remain uncontrolled. Chemical weed control is a preferred practice due to scarce and costly labour as well as lesser feasibility of mechanical or manual weeding (Chaudhari *et al.* 2017). Continuous use of a single herbicide may shift the weed flora in favour of the species that are not controlled, thus creating the problem in controlling weeds (Alemu *et al.* 2016). Therefore, use of herbicide in combinations which have broad-spectrum of weeds control and sometimes such combinations can give spectacularly good control at doses considerably below to those normally applied in single application. It may be additive or synergistic and safer to crops also. Nitrogen is a key factor in crop production and requires by plant out through growing period. Response of nitrogen varied with treatments like irrigation regimes, weed management, sowing dates, spacing, sowing method and other cultural treatments. Under the present experiment, the response of nitrogen levels may varied with different weed control treatments due to its effect on extent of crop – weed competition for light, space, nutrients which directly affect the plant growth (plant height, leaf area and dry matter accumulation *etc*), yield attribute and yield too, Therefore, its optimum level was be worked out for different weed management practices in wheat crop under zero till conditions which may be of immense help to improve the productivity, reduce the crop -weed competition and maximise the benefit

MATERIALS AND METHODS

A field experiment was conducted during *Rabi* season of 2015-16 and 2016-17 at research farm of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) to study the effect of different nitrogen levels and weed management practices on yield and economics of wheat. The Soil of experimental site was silty loam, having pH 8.3-8.6, organic carbon 0.38-0.39, available nitrogen 132.9-133.5 kg/ha, phosphorus 14.0-15.6 kg/ha and potash 240.0-246.3 kg/ha. The 20 treatment combinations consisted of four levels of nitrogen, *viz*. 90, 120, 150 and 180 kg N/ha, and five weed management practices, *viz*. weedy check, two hand weedings at 30 and 60 DAS, the post-emergence application (PoE) at 35 days after sowing (DAS) of herbicides (PoE) clodinafop + metsulfuron (60 + 4 g/ha), fenoxaprop + metsulfuron at (120 + 4 g/ha) and sulfosulfuron + metsulfuron (25 + 4 g/ha). and replicated three times in randomized block design. The post-emergence spray of herbicide was done with the help of manually operated knapsack sprayer fitted with flat-fan nozzle using water 500 L/ ha. The wheat variety '*NW 1014*' was sown at 20 cm apart row, using 125 kg seed/ha on December 20, 2015 and December 21, 2016. The crop was fertilized uniformly 60 P + 40 K kg/ha at sowing. The ½ dose of N at sowing time, and ¼ dose of N each at first and second irrigation, respectively. The crop was irrigated 4 times as per need of the crop. The data on dry matter accumulation by crop was collected by cutting the plant from ground level of 25 cm row length, first sun dried, and then kept in electric oven at 65^{0}C temperature to attain the constant weight. The data pertaining to yield attributes were collected on 10 spikes collected randomly from each plot. A quadrate of 0.25 x 0.25 m size was placed randomly at three spots, and weeds plants within quadrate were first pulled and then washed in clean water and counted species wise. Thereafter, weeds were sundried and kept in oven at 65 ^{0}C temperature until attainment of constraint weight. The data on weeds were transformed as per formula of ($\sqrt{x+0.5}$) for statistical analysis. The samples collected on weed and crop were analysed in laboratory for nitrogen contain (%) as per procedure (alkaline potassium permanganate method). The uptake of nitrogen was calculated by formula as given below.

$$\text{N-uptake (kg/ha)} = \frac{\text{N-contain (\%) in grain X grain yield (kg/ha)}}{100}$$

The data collected on crop and weeds were subjected to statistical analysis as per procedure (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Effect on weeds

Application of nitrogen from 90 to 180 kg/ha reduced the density of weed due to smothering effect of higher crop growth with increasing levels of nitrogen. However, in total biomass of weed was increased with corresponding increase in levels of nitrogen due to increased growth of individual weed plant, thus, resulted in higher weed biomass per unit area. Application of nitrogen from 90 to 180 kg/ha increased nitrogen uptake by weeds significantly at harvest stage due to higher weed bio mass, however difference between 90 kg and 120 kg, and 120 and 150 kg was at par with each other during both the years. The maximum uptake of nitrogen *i.e.* 27.12 and 27.12 kg/ha were recorded under weedy check plot in respective years. Hand weeding twice recorded significantly the lowest weed density and biomass and lowest uptake of nitrogen by weeds mainly due to efficient control of weed. Among the herbicidal treatments, clodinafop + metsulfuron (60 + 4 g/ha) recorded significantly the lowest weed density, weed biomass and lowest nitrogen uptake by weeds followed by sulfosulfuron + metsulfuron (25 + 4 g/ha) and fenoxaprop + metsulfuron (120 + 4 g/ha) owing to efficient control of weeds. Similar, results were reported by Singh *et al.* (2015).

Table 1. Weed density (no./m²) at harvest as affected by nitrogen levels and weed management practices in zero-till wheat

Treatment	*P. minor*		*C. dactylon*		*A. arvensis*		*M denticulata*		Other weeds		Total weeds	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Nitrogen (kg/ha)												
90	6.14 (38.80)	6.05 (37.71)	3.68 (13.63)	3.60 (13.09)	3.05 (9.05)	2.99 (8.70)	3.08 (9.57)	2.87 (8.24)	2.92 (8.22)	2.86 (7.86)	8.93 (79.27)	8.72 (75.6)
120	5.88 (35.60)	5.85 (35.27)	3.53 (12.50)	3.49 (12.24)	2.93 (8.30)	2.90 (8.14)	2.98 (8.95)	2.76 (7.56)	2.81 (7.54)	2.77 (7.35)	8.56 (72.89)	8.42 (70.56)
150	5.82 (34.89)	5.74 (33.87)	3.49 (12.25)	3.42 (11.76)	2.90 (8.13)	2.85 (7.82)	2.93 (8.59)	2.73 (7.41)	2.78 (7.39)	2.72 (7.06)	8.48 (71.25)	8.27 (67.92)
180	5.67 (33.11)	5.65 (32.82)	3.41 (11.63)	3.37 (11.39)	2.83 (7.72)	2.81 (7.58)	2.88 (8.33)	2.66 (7.03)	2.71 (7.01)	2.68 (6.84)	8.26 (67.8)	8.13 (65.66)
LSD (p=0.05)	0.27	0.26	0.15	0.16	0.12	0.12	0.13	0.12	0.09	0.10	0.37	0.37
Weed management												
Clodinafop + metsulfuron (60 + 4 g/ha)	5.01 (24.70)	4.97 (24.30)	3.08 (9.00)	3.03 (8.70)	2.43 (5.40)	2.49 (5.70)	2.53 (5.90)	2.40 (5.30)	2.45 (5.50)	2.41 (5.30)	7.14 (50.50)	7.06 (49.30)
Fenoxaprop + metsulfuron (120 + 4 g/ha)	5.88 (34.20)	5.85 (33.80)	3.39 (11.00)	3.36 (10.80)	3.16 (9.50)	3.19 (9.70)	2.77 (7.20)	2.57 (6.10)	3.00 (8.50)	2.95 (8.20)	8.42 (70.40)	8.31 (68.60)
Sulfosulfuron + metsulfuron (25 + 4 g/ha)	5.38 (28.50)	5.33 (28.00)	3.17 (9.60)	3.11 (9.20)	2.91 (8.00)	2.95 (8.20)	2.62 (6.40)	2.40 (5.30)	2.77 (7.20)	2.70 (6.80)	7.76 (59.7)	7.62 (57.55)
Weedy check	8.09 (65.10)	8.18 (66.70)	4.89 (23.50)	4.96 (24.20)	3.56 (12.20)	3.60 (12.50)	4.08 (16.20)	4.40 (18.90)	3.40 (11.30)	3.43 (11.10)	11.35 (128.3)	11.57 (133.4)
Hand weeding twice (30 and 60 DAS)	4.93 (23.90)	4.88 (23.40)	3.03 (8.70)	2.98 (8.40)	2.38 (5.20)	2.43 (5.40)	2.53 (5.90)	2.32 (4.90)	2.39 (5.20)	2.34 (5.00)	7.03 (48.9)	6.90 (47.10)
LSD (p=0.05)	0.30	0.29	0.17	0.17	0.14	0.14	0.15	0.13	0.10	0.11	0.41	0.42

*Data subjected to square root ($\sqrt{x+0.5}$) transformation and original data presented in parentheses

Table 2. Weed biomass and nitrogen uptake by weed as affected by nitrogen levels and weed management practices in zero-till wheat

Treatment	Weed biomass at harvest stage (g/m²)							
	Grassy		Broad-leaf		Sedge		Nitrogen uptake by weeds (kg/ha)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
N- kg/ha								
90	7.13(52.3)	7.08(51.6)	2.97(8.83)	2.74(7.45)	2.63(6.87)	2.37(5.49)	14.32	14.44
120	7.32(55.1)	7.19(53.2)	3.01(9.11)	2.81(7.85)	2.68(7.15)	2.45(5.89)	14.78	15.21
150	7.39(56.3)	7.34(55.4)	3.07(9.49)	2.83(8.01)	2.75(7.53)	2.48(6.05)	15.39	15.52
180	7.72(61.3)	7.59(59.3)	3.17(10.14)	2.95(8.73)	2.86(8.18)	2.61(6.77)	16.45	16.92
LSD (p=0.05)	0.34	0.33	0.13	0.12	0.12	0.10	0.85	0.84
Weed management								
Clodinafop + metsulfuron (60 + 4 g/ha)	6.32(39.5)	6.23(38.5)	2.60(6.25)	2.47(5.62)	2.34(4.98)	2.19(4.32)	11.56	11.00
Fenoxaprop + metsulfuron (120 + 4 g/ha)	7.41(54.6)	7.33(53.4)	2.85(7.63)	2.64(6.47)	2.57(6.13)	2.33(4.97)	14.15	13.83
Sulfosulfuron + metsulfuron (25 + 4 g/ha)	6.98(48.3)	6.89(47.2)	2.70(6.78)	2.38(5.19)	2.35(5.05)	2.21(4.42)	13.54	13.28
Weedy check	9.93(98.5)	10.05(100.9)	4.20(17.17)	4.52(20.03)	3.69(13.17)	4.06(16.03)	27.12	27.12
Hand weeding twice (30 and 60 DAS)	6.20(38.0)	6.11(37.0)	2.60(6.25)	2.47(5.62)	2.33(4.95)	1.97(3.39)	11.25	10.93
LSD (p=0.05)	0.39	0.37	0.14	0.15	0.13	0.12	0.94	0.95

*Data subjected to square root ($\sqrt{x+0.5}$) transformation and original data presented in parentheses

Effect on yield

Application of nitrogen 180 kg/ha gave significantly higher wheat grain (3.82 and 3.98 t/ha) and straw (5.14 and 5.23 t/ha) yields and higher nitrogen uptake being at par with 150 kg N/ha with grain (3.66 and 3.83 t/ha) and straw (5.12 and 5.22 t/ha) yield. This was mainly due to higher values of yield contributing characters owing to maximum availability of nitrogen with increasing N- levels resulted in higher grain and straw yield. Similar results have been reported by Upasani *et al.* (2013). Hand weeding twice was found at par with clodinafop + metsulfuron but produced significantly higher grain yield and straw yield during both the years. Among the herbicide treatments, clodinafop + metsulfuron produced higher wheat grain (3.70 and 3.90) and straw (5.14 and 5.23) yield followed by sulfosulfuron + metsulfuron. Hand weeding twice was at par with clodinafop + metsulfuron. Hand weeding twice recorded the highest gross (₹ 75000/

Table 3. Effect of nitrogen levels and weed management practices on wheat grain yield, nitrogen uptake and economics

Treatment	Grain yield (t/ha)		Straw yield (t/ha)		Nitrogen Uptake by crop (kg/ha)		Gross income (x10^3₹/ha)	Net income (x10^3₹/ha)	B:C ratio
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17			
N - kg/ha									
90	3.01	3.05	4.61	4.69	82.64	85.05	58.60	35.70	1.57
120	3.52	3.61	4.57	4.96	88.82	91.45	67.70	44.50	1.91
150	3.66	3.83	5.12	5.22	94.89	97.72	71.10	47.40	2.00
180	3.82	3.98	5.14	5.23	96.81	99.69	73.70	49.60	2.06
LSD (p=0.05)	0.19	0.19	0.26	0.25	4.65	4.72	-	-	-
Weed management									
Clodinafop + metsulfuron (60 + 4 g/ha)	3.70	3.90	5.14	5.23	96.08	98.96	72.10	48.90	2.11
Fenoxaprop + metsulfuron (120 + 4 g/ha)	3.47	3.55	4.84	4.93	88.35	90.93	66.80	44.20	1.96
Sulfosulfuron + metsulfuron (25 + 4 g/ha)	3.68	3.75	4.95	5.04	91.02	93.74	70.30	47.00	2.02
Weedy check	2.87	2.76	4.57	4.49	83.31	80.92	54.70	33.10	1.54
Hand weeding twice (30 and 60 DAS)	3.90	4.03	5.26	5.36	97.57	100.46	75.00	50.50	2.05
LSD (p=0.05)	0.21	0.21	0.29	0.28	5.19	5.28	-	-	-

ha) and net income (₹ 50500/ha) followed by clodinafop + metsulfuron (₹ 72100/ha) and (₹ 48900/ha). However, clodinafop + metsulfuron recorded higher B:C ratio (2.11) than twice hand weeding (2.05) due to higher cost incurred with hand weeding twice.

It was concluded that application of 180 kg N/ha along with clodinafop + metsulfuron PoE produced higher wheat yield and benefit cost ratio under zero-tillage situation.

REFERENCES

Alemu Nano, Sharma JJ and Iticha Firdissa. 2016. Effect of weed management practices and nitrogen levels on weeds, yield components and yield of bread wheat (*Triticum aestivum* L.) at Kulumsa, South eastern Ethiopia. *World Journal of Agricultural Sciences* **12**(6): 437-448.

Chaudhari DD, Patel VJ, Patel HK, Mishra A, Patel BD and Patel RB. 2017. Assessment of pre-mix broad spectrum herbicides for weed management in wheat. *Indian Journal of Weed Science* **49**(1): 33–35.

DAC&FW. 2018. Department of Agriculture, Cooperation & Farmers Welfare Directorate of Economics and Statistics Page 75-76.

Dangwal LR, Aman DS, Singh T and Sharma C. 2010. Effect of weeds on the yield of wheat crop in Tehsil Nowshera. *Journal of American Science* **6**(10): 405-407.

Gomez KA and Gomez AA. 1984. *Statistical Procedure for Agriculture Research*. Second Edition. John with and Sons Inc. New York.

Singh M, Singh MK, Singh SP and Sahu R. 2015. Herbicide and nitrogen application effects on weeds and yield of wheat. *Indian Journal of Weed Science* **47**(2): 125–130.

Upasani RR, Thakur R, Puran AN and Singh MK. 2013. Effect of nitrogen and weed control on productivity of wheat. *Indian Journal of Weed Science* **45**(2): 106–111

Indian Journal of Weed Science **52**(3): 245–249, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Effect of organic weed management practices on weed control and yield of soybean-gram cropping system under irrigated condition

A.A. Chavan*, W.N. Narkhede and A.S. Karle

Department of Agronomy, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra 431 402, India

**Email: ashachavan1992@gmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00047.7

Type of article: Research article

Received : 19 March 2020
Revised : 27 July 2020
Accepted : 29 July 2020

Key words

Organic, Soil solarization, Soybean-gram, Stale seed bed, Weed management

ABSTRACT

The significantly lower weed density and biomass, at 40 days after seeding (DAS) was recorded in weed free plots followed by soil solarization with 25 µ polythene mulch during summer + one hand weeding at 25 DAS in soybean and gram during both the years. Among the weed management practices, combination of stale seedbed + reduced spacing + mulching with wheat straw (2 t/ha) + one HW at 25 DAS recorded higher soybean equivalent yield. Higher net returns and benefit: cost ratio was observed in soybean + sun hemp incorporation after 35-40 DAS in *Kharif* and gram + safflower (2:1) intercropping in *Rabi* season, followed by stale seedbed + reduced spacing + mulching with wheat straw (2 t/ha) + one HW at 25 DAS. Application of two hand weeding (20-25 and 45-50 DAS) recorded higher values of yield attributes.

INTRODUCTION

Soybean (*Glycine max* L.) is a leguminous crop and belongs to family leguminosae with sub family papilionaceae. Soybean is a "*Golden bean*" of 21th century mainly due to its high protein (40-42%) and oil (20%) contents. Being a rainy season crop, it faces severe weed competition during early stages of crop growth, resulting in loss of about 40-60% of the potential yield, depending on the weed intensity, nature, environmental condition and duration of weed competition (Mishra *et al.* 2002). Gram (*Cicer arietinum*) is one of the most important pulse crop of Maharashtra during *Rabi*. Kumar *et al.* (2014) reported that presence of weeds throughout the crop season reduced the seed yield of gram up to 68%. Weeds are widely reported as a key constraint in organic agriculture. Higher infestation of weeds in crops tends to decrease crop yields by increasing competition for water, sunlight and nutrients while serving as host plants for pests and diseases. The indiscriminate use of herbicides has resulted in loss of biodiversity, environmental and health problems, and development of resistance. In organic farming, cultural and mechanical methods are necessary to break the weed cycle. Soybean-gram is important cropping sequence adopted in Maharashtra in irrigated situation. The research work carried out on organic weed management in soybean-gram cropping sequence is very limited. Hence, the present investigation was conducted to evaluate the non-chemical weed management options in soybean-gram cropping sequence.

MATERIALS AND METHODS

Field experiments were conducted at Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (Maharashtra) during 2017-18 and 2018-19. Geographically, Parbhani is situated at 19^{0}16' North latitude and 76^{0}47' East longitude and at an altitude of 409 meters above sea level in Marathwada division encompassed by 17^0 35' to 20^0 40' North and 74^0 49' to 78^0 15' East geographical boundaries. The soil of the experimental plot was clayey in texture (52.32 and 53.60% clay), low in organic carbon (0.50 and 0.56%) and available nitrogen (222.48 and 231.18 kg/ha), medium in available phosphorus (17.52 and 18.32 kg/ha), high in available potassium (545.50 and 549.18 kg/ha) and slightly alkaline in reaction (pH-8.00 and 8.10) during both the year respectively.

The experiment was laid out in a randomized block design with three replications. The weed management treatments were: two hand weedings (HW) at 20-25 and 45-50 DAS, one hoeing 20-25 DAS + one HW at 45-50 DAS, soybean + sunhemp incorporation after 35-40 DAS in *Kharif* season and gram + safflower (2:1) in *Rabi* season, stale seed bed + reduced spacing + mulching with wheat straw (2 t/ha) + one HW at 25 DAS, soil mulch at the time of sowing + one hand pulling at 25 DAS, incorporation of neem cake 1.5 t/ha 15 days before sowing + one HW at 25 DAS, soil solarization with 25 µ polythene mulch during summer + one HW at 25 DAS, mulching with straw, weed free and weedy check. In soybean, sunhemp was sown in between the two rows and it was incorporated at 30 to 35 days after seeding through wooden plough, before start of flowering. The sunhemp was sown simultaneously with tractor drawn seed drill at 20 kg/ha. The wheat straw applied manually through broadcasting in soybean at 5.0 t/ha available at the rate ₹ 1 per kg. Gram + safflower were sown in 2:1 ratio at 30 cm to reduce weed flora in field due to high population density. The observations on weed density and weed biomass were taken randomly from 1.0 m^2 quadrat from net plot area from each treatment.

RESULTS AND DISCUSSION

Weed flora

The predominant weed flora found in soybean crop were *Cynodon dactylon, Brachiaria eruciformis, Commelina benghalensis, Cyperus rotundus, Phyllanthus niruri, Parthenium hysterophorus* and *Euphorbia geniculata*. The predominant weed flora found in gram crop were *Cynodon dactylon, Cyperus rotundus, Phyllanthus niruri, Convolvulus arvensis* and *Amaranthus viridis* during both the years of the study. Weed density at 40 days after seeding of soybean and gram given in **Table 1** and **2**, respectively.

Effect on weeds

During both the years at 40 DAS, significantly the lower biomass of monocot, dicot and total weeds was recorded under weed free treatment followed by soil solarization for 30 days with 25 µ polythene mulch during summer + one HW at 25 DAS and stale seed bed + reduced spacing + mulching with wheat straw (2 t/ha) + one HW at 25 DAS in both soybean and gram **(Table 3** and **4)**. Significantly higher biomass of monocot, dicot and total weeds was recorded in weedy check.

Yield

During first year, stale seed bed + reduced spacing + mulching with wheat straw (2 t/ha) + one HW (25 DAS) recorded significantly more seed yield (2.54 t/ha) was on par with weed free (2.42 t/ha) and two hand weeding's at 20-25 and 45-50 DAS (2.37

Table 1. Effect of different treatments on weed density (no./m^2) in soybean at 40 days after seeding

Treatment	Monocot			Dicot			Total weed		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Two hand weeding (HW) at 20-25 and 45-50 DAS	12.00	15.00	13.5	5.00	7.13	6.07	17.00	22.13	19.57
One hoeing (20-25 DAS) + one HW (45-50 DAS)	14.47	17.40	15.9	5.40	7.60	6.50	19.87	25.00	22.43
Soybean + sunhemp incorporation after 35-40 DAS	8.60	11.53	10.07	4.60	6.67	5.63	13.20	18.20	15.70
Stale seed bed + reduced spacing + mulching with wheat straw (2 t/ha) + one HW (25 DAS)	7.57	10.50	9.03	3.93	5.60	4.77	11.50	16.10	13.80
Soil mulch at the time of sowing + one hand pulling at 25 DAS	15.67	19.00	17.33	6.67	8.83	7.75	22.33	27.83	25.08
Incorporation of neem cake 1.5 t/ha (15 days before sowing) + one HW (25 DAS)	12.13	15.47	13.80	5.13	7.20	6.17	17.27	22.67	19.97
Soil solarization with 25 µ polythene mulch during summer + one HW (25 DAS)	6.47	9.47	7.97	3.00	4.73	3.87	9.47	14.20	11.83
Mulching with straw	29.87	33.20	31.53	16.00	18.67	17.33	45.87	51.87	48.87
Weed free	1.33	2.40	1.87	1.30	3.30	2.30	2.63	5.70	4.17
Weedy check	31.20	35.20	33.20	18.00	20.73	19.37	49.20	55.93	52.57
LSD (p=0.05)	2.74	2.90	2.92	2.97	3.17	3.14	4.64	4.97	4.94

Table 2. Effect of different treatments on weed density (no./m^2) in gram at 40 days after seeding

Treatment	Monocot			Dicot			Total weed		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Two hand weeding (HW) at 20-25 and 45-50 DAS	10.67	12.80	11.73	4.43	6.40	5.42	15.10	19.20	17.15
One hoeing (20-25 DAS) + one HW (45-50 DAS)	13.87	16.95	15.41	6.58	9.50	8.04	20.45	26.45	23.45
Gram + safflower (2:1)	16.53	18.67	17.60	9.10	11.17	10.13	25.63	29.83	27.73
Stale seed bed + reduced spacing + mulching with wheat straw (2 t/ha) + one HW (25 DAS)	7.23	9.45	8.34	3.00	4.13	3.57	10.23	13.58	11.91
Soil mulch at the time of sowing + one hand pulling at 25 DAS	15.33	17.20	16.27	7.90	9.77	8.83	23.23	26.97	25.10
Incorporation of neem cake 1.5 t/ha 15 days before sowing + one HW at 25 DAS	10.87	13.27	12.07	4.60	6.50	5.55	15.47	19.77	17.62
Soil solarization with 25 µ polythene mulch during summer + one hand weeding at 25 DAS	6.13	8.40	7.27	3.18	4.30	3.74	9.32	12.70	11.01
Mulching with straw	30.53	33.73	32.13	17.50	20.50	19.00	48.03	54.23	51.13
Weed free	1.87	3.87	2.87	1.50	2.75	2.13	3.37	6.62	4.99
Weedy check	31.20	34.40	32.80	19.20	22.10	20.65	50.40	56.50	53.45
LSD (p=0.05)	2.87	2.99	3.00	1.86	1.97	2.00	3.47	4.00	3.89

t/ha). Lower seed yield (1.15 t/ha) was noticed with weedy check. Similar trend was noticed during second year and in pooled results. (**Table 5**).

In gram all the weed control treatments were found to be significantly superior over the weedy check during both the year. Gram + safflower (2:1) intercropping recorded significantly more seed yield which was at par with stale seed bed + reduced spacing + mulching with wheat straw (2 t/ha) + one HW (25 DAS), weed free, soil solarization with 25 µ polythene mulch during summer + one HW (25 DAS) and incorporation of neem cake 1.5 tonne/ ha 15 days before sowing + one HW (25 DAS) and significantly superior over rest of the treatments.

In pooled data, more seed yield was recorded by gram + safflower (2:1) treatment (2.62 t/ha) which on par with, stale seed bed + reduced spacing + mulching with wheat straw (2 t/ha) + one HW (25 DAS), weed free, soil solarization with 25 µ polythene mulch during summer + one HW (25 DAS) and incorporation of neem cake 1.5 t/ha 15 days before sowing + one HW (25 DAS) and two hand weedings at 20-25 and 45-50 DAS. **(Table 6)**. It might be attributed to lesser competition offered by weeds for light, water and nutrients which resulted in more uptake of nutrients and produced more photosynthates. Lower yield was noticed with weedy check. This is due to more weed competition with crop for light, water and nutrients produced less photosynthates. Similar results reported by Rathod *et al*. (2017), Pedde *et al*. (2013), Singh and Jain (2017).

Yield attributes

Significantly more number of pods/plant, weight of pods/plant, weight of seeds/plant, number of seeds/pod and test weight of soybean were recorded with two hand weeding at 20-25 and 45-50 DAS, which was at par with soil solarization with 25 µ

Table 3. Effect of different treatments on weed biomass (g/m²) in soybean at 40 days after seeding

Treatment	Monocot			Dicot			Total weed		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Two hand weeding (HW) at 20-25 and 45-50 DAS	6.61	8.61	7.61	3.20	5.10	4.15	9.81	13.71	11.76
One hoeing (20-25 DAS) + one HW (45-50 DAS)	8.07	11.15	9.61	3.46	7.13	5.29	11.53	18.27	14.90
Soybean + sunhemp incorporation after 35-40 DAS	4.93	7.48	6.21	2.95	4.85	3.90	7.88	12.33	10.11
Stale seed bed + reduced spacing +mulching with wheat straw (2 t/ha) + one HW (25 DAS)	4.12	7.00	5.56	2.51	4.45	3.48	6.63	11.45	9.04
Soil mulch at the time of sowing + one hand pulling at 25 DAS	9.03	13.00	11.02	5.03	8.16	6.60	14.07	21.16	17.61
Incorporation of neem cake 1.5 tonne/ ha (15 days before sowing) + one HW (25 DAS)	6.80	8.72	7.76	3.29	5.37	4.33	10.09	14.08	12.09
Soil solarization with 25 µ polythene mulch during summer + one HW (25 DAS)	3.61	5.52	4.57	2.00	3.60	2.80	5.61	9.12	7.37
Mulching with straw	16.67	22.91	19.79	12.20	15.53	13.87	28.87	38.44	33.66
Weed free	0.74	2.40	1.57	0.83	1.80	1.32	1.57	4.20	2.89
Weedy check	17.42	23.23	20.33	13.27	16.27	14.77	30.68	39.50	35.09
LSD (p=0.05)	1.54	2.27	2.22	2.12	2.26	2.30	2.95	3.88	3.81

Table 4. Effect of different treatments on mean weed biomass (g/m²) in gram at 40 days after seeding

Treatment	Monocot			Dicot			Total weed		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Two hand weeding (HW) at 20-25 and 45-50 DAS	5.95	9.00	7.48	3.37	4.42	3.90	9.32	13.42	11.37
One hoeing (20-25 DAS) + one HW (45-50 DAS)	8.74	12.38	10.56	5.84	6.94	6.39	14.58	19.32	16.95
Gram + safflower (2:1)	10.71	14.80	12.76	9.02	10.38	9.70	19.73	25.18	22.46
Stale seed bed + reduced spacing + mulching with wheat straw (2 t/ha) + one HW (25 DAS)	4.03	7.70	5.87	2.82	3.90	3.36	6.85	11.60	9.23
Soil mulch at the time of sowing + one hand pulling at 25 DAS	9.22	13.38	11.30	7.04	8.72	7.88	16.26	22.09	19.18
Incorporation of neem cake 1.5 t/ha 15 days before sowing + one hand weeding at 25 DAS	6.06	9.13	7.60	3.45	4.68	4.07	9.51	13.81	11.66
Soil solarization with 25 µ polythene mulch during summer + one hand weeding at 25 DAS	3.42	6.42	4.92	2.38	3.56	2.97	5.80	9.98	7.89
Mulching with straw	17.04	21.18	19.11	12.70	15.23	13.97	29.74	36.42	33.08
Weed free	1.95	3.20	2.58	1.30	2.30	1.80	3.25	5.50	4.38
Weedy check	17.42	22.08	19.75	12.93	15.73	14.33	30.35	37.82	34.08
LSD (p=0.05)	1.47	1.76	1.76	1.54	1.69	1.70	2.26	2.33	2.52

polythene mulch during summer + one hand weeding at 25 DAS treatment and significantly superior over rest of the treatments. It might be due to lowering crop-weed competition during critical crop growth period at pod development stage. Similar findings were also reported by Patel *et al.* (2018), Rathod *et al.* (2017), Yadav and Shaikh (2009), Rai *et al.* (2016) Sharma *et al.* (2016), Purena *et al* (2015). **(Table 5)**.

Significantly more number of pods/plant, weight of pods/plant, weight of seeds/plant, number of seeds/plant, number of seed/pod and test weight of gram were recorded with weed free which was at par with the soil solarization with 25 µ polythene mulch during summer + one HW (25 DAS), incorporation of neem cake 1.5 t/ha 15 days before sowing + one HW (25 DAS) and two hand weeding at 20-25 and 45-50 DAS. It might be due to the complete elimination of weeds at critical period of crop-weed competition resulting better plant growth and higher yield attributing parameters These findings are in accordance with those of Ratnam *et al.* (2011) and Gore *et al.* (2018) **(Table 6)**.

Soybean equivalent yield and economics

During both the years, significantly higher soybean equivalent yield of system was recorded by stale seedbed + reduced spacing (30 cm) + mulching with wheat straw (2 t/ha) + one HW at 25 DAS which was at par with soybean + sunhemp incorporation after 35-40 DAS in *Kharif*, and gram + safflower (2:1) in *Rabi* season. Lower soybean equivalent yield was observed with weedy check **(Table 7)**. Suppression of weeds and higher yield in gram + safflower (2:1) intercropping was due to reduced spacing and higher plant density. Lower soybean equivalent yield was observed with weedy check. Das and Yaduraju (2008) reported similar findings in respect of soybean equivalent yield.

Table 5. Effect of different treatments on mean seed yield and yield attributes of soybean

Treatment	Yield (t/ha)			Weight of pods/plant (g)		Weight of seeds/plant(g)		No. of seeds/plant	
	2017-18	2018-19	Pooled	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Two hand weeding (HW) at 20-25 and 45-50 DAS	2.37	2.56	2.47	17.99	20.20	12.80	13.15	90.06	95.20
One hoeing (20-25 DAS) + one HW (45-50 DAS)	1.97	2.13	2.05	15.73	17.06	9.77	11.03	68.73	79.89
Soybean + Sunhemp incorporation after 35-40 DAS	2.20	2.41	2.30	14.52	16.47	8.69	9.57	61.13	69.30
Stale seed bed + reduced spacing + mulching with wheat straw (2 t/ha) + one HW (25 DAS)	2.54	2.77	2.66	14.32	16.23	8.53	9.33	59.33	67.58
Soil mulch at the time of sowing + one hand pulling at 25 DAS	1.36	1.52	1.44	14.80	16.92	8.74	10.59	63.23	76.71
Incorporation of neem cake 1.5 t/ha 15 days before sowing + one hand weeding at 25 DAS	2.15	2.33	2.24	15.83	17.74	9.88	12.14	69.51	87.88
Soil solarization with 25 µ polythene mulch during summer + one hand weeding at 25 DAS	2.18	2.37	2.27	17.13	19.05	12.45	12.62	87.62	91.36
Mulching with straw	1.25	1.38	1.32	10.57	11.96	7.62	8.32	52.95	60.22
Weed free	2.42	2.65	2.54	19.48	21.38	14.04	14.48	98.81	104.88
Weedy check	1.15	1.29	1.22	10.31	11.40	7.50	8.10	52.78	58.67
LSD (p=0.05)	0.29	0.35	0.33	2.49	2.77	1.60	2.08	11.29	15.03

Table 6. Effect of different treatments on mean seed yield and yield attributes of gram

Treatment	Yield (t/ha)			Weight of pods/plant (g)		Weight of seeds/plant (g)		No. of seeds/plant	
	2017-18	2018-19	Pooled	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Two hand weeding (HW) at 20-25 and 45-50 DAS	2.39	2.27	2.33	17.57	15.54	11.90	11.61	56.41	48.49
One hoeing (20-25 DAS) + one HW (45-50 DAS)	2.27	2.13	2.20	15.75	14.42	10.58	9.87	50.16	43.27
Gram + safflower (2:1)	2.77	2.47	2.62	10.35	9.69	6.88	6.43	32.60	30.77
Stale seed bed + reduced spacing + mulching with wheat straw (2 t/ha) + one HW (25 DAS)	2.58	2.39	2.49	10.97	9.95	7.28	6.63	34.50	31.61
Soil mulch at the time of sowing + one hand pulling at 25 DAS	2.11	2.09	2.10	14.36	13.42	9.70	9.62	45.97	42.93
Incorporation of neem cake 1.5 t/ha 15 days before sowing + one hand weeding at 25 DAS	2.47	2.41	2.44	17.90	19.72	12.12	12.22	57.43	54.13
Soil solarization with 25 µ polythene mulch during summer + one hand weeding at 25 DAS	2.48	2.43	2.45	18.07	21.32	12.43	12.30	58.89	58.30
Mulching with straw	1.75	1.21	1.48	13.41	9.22	7.94	6.14	37.62	25.93
Weed free	2.50	2.41	2.45	20.31	18.16	13.49	12.20	63.94	51.02
Weedy check	1.55	1.12	1.33	12.28	8.84	6.82	5.74	32.32	23.87
LSD (p=0.05)	0.30	0.29	0.32	3.32	3.35	2.49	1.99	10.09	9.25

Table 7. Soybean equivalent yield and monetary returns as influenced by different weed management treatment

Treatment	Soybean equivalent yield (t/ha)			Gross monetary returns (x10³₹/ha)			Net monetary returns (x10³₹/ha)			Benefit: Cost ratio (B:C)		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Two hand weeding (HW) at 20-25 and 45-50 DAS	5.36	5.65	5.50	147.8	192.1	170.0	65.4	98.4	81.9	1.80	2.05	1.93
One hoeing (20-25 DAS) + one HW (45-50 DAS)	4.81	5.02	4.92	132.6	170.8	151.7	60.0	89.2	74.6	1.84	2.09	1.97
Soybean + sunhemp incorporation after 35-40 DAS in *Kharif* and gram + safflower (2:1) in *Rabi* season	5.66	5.76	5.71	156.3	195.9	176.1	95.3	124.7	110.0	2.60	2.77	2.69
Stale seed bed + reduced spacing + mulching with wheat straw (2 t/ha) + one HW (25 DAS)	5.77	6.02	5.89	159.1	204.7	181.9	80.7	113.4	97.0	2.04	2.24	2.14
Soil mulch at the time of sowing + one hand pulling at 25 DAS	4.00	4.36	4.18	110.3	148.3	129.3	41.7	70.3	56.0	1.60	1.90	1.75
Incorporation of neem cake 1.5 t/ha 15 days before sowing + one hand weeding at 25 DAS	5.24	5.61	5.43	144.7	190.8	167.7	31.1	61.6	46.3	1.24	1.48	1.36
Soil solarization with 25 µ polythene mulch during summer + one hand weeding at 25 DAS	5.28	5.67	5.47	145.7	192.7	169.2	42.1	77.8	59.9	1.42	1.68	1.55
Mulching with straw	3.44	3.03	3.23	94.8	102.9	98.8	35.3	30.3	32.8	1.53	1.42	1.48
Weed free	5.54	5.93	5.74	152.9	201.5	177.2	68.3	104.8	86.6	1.82	2.08	1.95
Weedy check	3.09	2.81	2.95	85.2	95.6	90.4	28.8	28.9	28.8	1.50	1.43	1.47
LSD (p=0.05)	0.54	0.53	0.57	14.9	17.9	19.2	15.6	17.9	19.4	-	-	-

Soybean + sunhemp incorporation after 35-40 DAS in *Kharif* and gram + safflower (2:1) in *Rabi* season recorded significantly higher net returns of system (₹ 95257/ha) which was at par with stale seed bed + reduced spacing + mulching with wheat straw (2 t/ha) + one HW at 25 DAS (₹ 80668/ha) and significantly superior over rest of the treatments. It might be due to higher seed yield and less cost of cultivation in these treatments. Kumar and Das (2008) reported similar findings in respect of system economics. Least net monetary returns were recorded by weedy check treatment (₹ 28769/ha). Similar kind of trend was noticed during second year and in pooled results. The higher B:C ratio (2.60) was observed with soybean + sunhemp incorporation after 35-40 DAS) in *Kharif* and gram + safflower (2:1)) in *Rabi* season treatment followed by stale seed bed + reduced spacing +mulching with wheat straw (2 t/ha) + one HW at 25 DAS (2.04).

Conclusion

In organic agriculture, application of stale seed bed + reduced spacing + mulching with wheat straw (2 t/ha) + one HW at 25 DAS recorded higher soybean equivalent yield and profits, followed by soybean + sunhemp incorporation after 35-40 DAS in *Kharif* and gram + safflower (2:1) in *Rabi* season. Soil solarization with 25 µ polythene mulch during summer + one HW (25 DAS) recorded lower weed density and biomass at 40 days after sowing.

REFERENCES

Das TK and Yaduraju NT. 2008. Effect of soil solarization and crop husbandry practices on weed species competition and dynamics in soybean-wheat cropping system. *Indian Journal of Weed Science* **40**(1&2): 1–5.

Gore AK, Chavan AS, Gokhale DN and Thombre KM. 2018. Evaluation of new herbicides on weed flora and productivity of chickpea. *International Journal of Current Microbiology and Applied Sciences* **7**(5): 3682–3687.

Kumar M and Das TK. 2008. Integrated weed management for system productivity and economics in soybean –wheat system. *Indian Journal of Agronomy* **53**(3): 189–194.

Kumar N, Nandal DP and Punia SS. 2014. Weed management in chickpea under irrigated condition. *Indian Journal of Weed Science* **46**(3): 300–301.

Mishra JS, Singh VP and Yaduraju NT. 2002. Interference of common day flower in soybean. *Indian Journal of Weed Science* **34**: 295–296.

Patel S, Dhonde MB and Kamble AB. 2018. Effect of integrated weed management on growth and yield of soybean. *International Journal of Agriculture Sciences* **10**(10): 6058–6062.

Purena H, Lakpale R, Khare C and Ghritlahare A. 2015. Effect of herbicide and cultural practices for effective weed management in soybean. *Indian Journal of Agronomy* **60**(1): 160–162.

Rathod PS, Patil DH and Dodamani BM. 2017. Integrated weed management in chickpea under rainfed conditions of Karnataka, India. *International Journalof Legume Research* **40**(3): 580–585.

Rai CL, Tiwari RK, Sirothia P and Pandey S. 2016. Intercropping and weed management effects on weed dynamics, productivity and economics of pigeonpea. *Indian Journal of Weed Science* **48**(1): 44–47.

Ratnam M, Rao AS and Reddy TY. 2011. Integrated weed management in chickpea. *Indian Journal of Weed Science* **43**(1&2): 70–72.

Sharma NK, Mundra SL and SontaraKalita. 2016. Effect of weed control on growth and productivity of soybean. *Indian Journal of Weed Science* **48**(1): 90–92.

Yadav VK and Shaikh AA. 2009. Effect of integrated weed management on productivity of soybean. *Haryana Journal of Agronomy* **25**(1&2): 84–85.

Indian Journal of Weed Science **52**(3): 250–253, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Effectiveness of herbicide mixture on weeds and yield of summer groundnut

B.D. Patel*, D.D. Chaudhari, V.B. Mor, V.J. Patel, and H.K. Patel

B.A. College of Agriculture, Anand Agricultural University, Anand, Gujarat 388 110, India

**Email: bdpatel62@yahoo.com*

Article information

DOI: 10.5958/0974-8164.2020.00048.9

Type of article: Research article

Received : 7 May 2020
Revised : 17 September 2020
Accepted : 19 September 2020

Key words
Haulm, Herbicides, Weed dry weight

ABSTRACT

A field experiment was conducted during two consecutive summer season of 2018 and 2019 in loamy sand soil at B. A. College of Agriculture, Anand Agricultural University, Anand to study the effect of integrated weed management in summer groundnut. Results indicated that pre-emergence application of oxyfluorfen 180 g/ha PE *fb* interculturing (IC) + hand weeding (HW) at 40 DAS found to be effective for controlling weeds, and higher pod yield (3.99 t/ha) of groundnut, followed by oxyfluorfen 180 g/ha PE *fb* imazethapyr 100 g/ha PoE, IC *fb* HW at 20 and 40 DAS, oxyfluorfen 180 g/ha PE *fb* imazethapyr + imazamox 70 g/ha PoE (pre-mix) and fluazifop-p-butyl + fomesafen 250 g/ha ePoE (pre-mix) *fb* IC + HW at 40 DAS.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important edible oilseed crop of India popularly known as peanut or monkey nut belongs to the family leguminosae. Among all oilseed crops, groundnut accounts for more than 40-50% in area and 60-70% in production in the country. Gujarat is the largest producer contributing 25% of the total production of groundnut followed by Andhra Pradesh, Tamil Nadu and Karnataka (Sameer *et al.* 2014). Heavy weed infestation appears to be the most serious menace in groundnut production causing extensive losses. Because of its short stature and initial slow growth in comparison to fast growing weeds, weeds smother this crop at every stage by sharing water, nutrients, space, solar radiation and other resources resulting in yield losses ranging between 15-75% (Jat *et al.* 2011). Hence, for achieving potential yield, timely and effective weed control during the critical period of weed competition become necessary. Application of selective herbicides may control limited weed species but may not be effective on complex weed flora. Sometimes pre-emergence herbicides weed control for a limited period and therefore, late emerging weeds escape to applied herbicide. There is ample scope for controlling weeds by application of early post-emergence herbicides, herbicide mixtures or with integration of mechanical method. Moreover, recently many pre-mix herbicides are available in the market which provide effective control of weeds with less total active ingredient. Looking to this, an experiment was conducted to study the integrated weed management in summer groundnut under middle Gujarat conditions.

MATERIALS AND METHODS

A field experiment was conducted during summer season 2018 and 2019 in loamy sand soil at B.A. College of Agriculture, Anand Agricultural University, Anand. The soil of the experimental field was low in available nitrogen and medium in available phosphorous and high in potassium. Twelve weed management practices consisted of oxyfluorfen 180 g/ha pre-emergence (PE) *fb* interculturing (IC) + HW at 40 DAS, oxyfluorfen 180 g/ha PE *fb* imazethapyr 100 g/ha post-emergence (PoE), oxyfluorfen 180 g/ha PE *fb* imazethapyr + imazamox 70 g/ha PoE (pre-mix), quizalofop-ethyl 50 g/ha early post-emergence (ePoE) *fb* interculturing (IC) + hand weeding (HW) at 40 DAS, imazethapyr 100 g/ha ePoE *fb* interculturing (IC) + hand weeding (HW) at 40 DAS, imazethapyr 150 g/ha PoE, imazethapyr + imazamox 70 g/ha PoE (pre-mix), imazethapyr + imazamox 70 g/ha ePoE (pre-mix) *fb* HW at 40 DAS, fluazifop-p-butyl + fomesafen 250 g/ha PoE (pre-mix), fluazifop-p-butyl + fomesafen 250 g/ha ePoE (pre-mix) *fb* interculturing (IC) + HW at 40 DAS, interculturing (IC) *fb* HW at 20 and 40 DAS and weedy check were laid out in a randomized block design with three replications. Groundnut cv. '*TG 37*' was sown on 20 and 6 February, 2018 and 2019, respectively keeping spacing of 30 x 10 cm by using seed rate of 120 kg/ha. The crop was harvested on 1 and 7 June, 2018 and 2019, respectively. Pre-and post-emergence herbicides were applied by using battery operated knapsack sprayer fitted with flat-fan nozzle by mixing in 500 litre of water/ha as per treatments. The crop was fertilizer with recommended rate of fertilizer with

25 kg N and 50 kg P/ha in the form of urea and single super phosphate, respectively as a basal dose.

Density and dry weight of weeds were recorded from randomly selected four spots by using 0.25 m^2 quadrate from net plot through destructive sampling at harvest. Weed control efficiency (WCE) was calculated on the basis of standard formulas suggested by Maity and Mukherjee (2011). The yield reduction (%) owing to the presence of weeds was estimated by using the formula suggested by Kumar and Gill (1969) and expressed as weed index (WI). Other growth and yield attributing observations were also recorded from net plot area. Seed index was worked out based on the counting of 100 seeds. Shelling percentage was calculated based on the following formula

$$\text{Shelling percentage (\%)} = \frac{\text{Weight of seed}}{\text{Weight of unshelled pods}} \times 100$$

Data of various observations during the experiment period were statistically analysed as per the standard procedure developed by Cochran and Cox (1957).

RESULTS AND DISCUSSION

Effect on weeds

Experimental field was infested with *Eleusine indica* (24.1%), *Dactyloctenium aegyptium* (15.0%), *Eragrostis major* (9.28%) and *Digitaria sanguinalis* (4.81%) in monocot weeds whereas, *Trianthema monogyna* (21.5%), *Phyllanthus niruri* (18.0%), *Digera arvensis* (2.40%) and *Amaranthus viridis* (2.18%) in dicot weed category. Density and dry biomass of total weeds (6.49/m^2 and 10.4 g/m^2, respectively) was recorded significantly lower under application of oxyfluorfen 180 g/ha PE *fb* IC + HW at 40 DAS at harvest (**Table 1**). Chandolia *et al.* (2010) also reported that application of oxyfluorfen along with hand weeding at 30 DAS was found more effective in controlling weeds at all the stages of crop growth. Among all the weed management practices, application of oxyfluorfen 180 g/ha PE *fb* IC + HW at 40 DAS stood first by providing maximum weed control efficiency followed by oxyfluorfen 180 g/ha PE *fb* imazethapyr 100 g/ha PoE, oxyfluorfen 180 g/ ha PE *fb* imazethapyr + imazamox 70 g/ha PoE and fluazifop-p-butyl + fomesafen 250 g/ha ePoE (pre-mix) *fb* IC + HW at 40 DAS. Higher weed control

Table 1. Density and dry biomass of total weeds, WCE and weed index as influenced by weed management practices in summer groundnut

Treatment	Weed density at harvest (no./m^2)			Weed dry biomass at harvest (g/m^2)			Weed control efficiency (%)			Weed index (%)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Oxyfluorfen 180 g/ha PE *fb* IC + HW at 40 DAS	6.80^{d} (45.3)	6.19^{h} (37.3)	6.49^{h} (41.3)	10.7^{e} (114)	10.0^{e} (101)	10.4^{f} (107)	75.7	78.5	77.2	-	-	-
Oxyfluorfen 180 g/ha PE *fb* imazethapyr 100 g/ha PoE	7.34^{d} (53.3)	6.56^{fgh} (42.7)	6.95^{gh} (48.0)	10.9^{e} (119)	10.4^{e} (107)	10.6^{def} (113)	74.7	77.2	75.9	1.1	2.5	2.0
Oxyfluorfen 180 g/ha PE *fb* imazethapyr + imazamox 70 g/ha PoE (premix)	8.29^{cd} (68.0)	8.13^{defg} (66.7)	8.21^{def} (67.3)	11.7^{e} (136)	10.7^{e} (114)	11.2^{def} (125)	71.1	75.7	73.3	2.6	7.6	5.5
Quizalofop-ethyl 50 g/ha ePoE *fb* IC + HW at 40 DAS	8.11^{cd} (65.3)	6.67^{cdef} (74.7)	8.39^{de} (70.0)	12.1^{de} (146)	11.6^{e} (135)	11.9^{de} (141)	68.9	71.2	69.9	28.5	27.6	28.1
Imazethapyr 100 g/ha ePoE *fb* IC + HW at 40 DAS	8.10^{cd} (64.7)	6.69^{fgh} (44.0)	7.40^{efgh} (54.3)	11.9^{de} (142)	12.0^{de} (143)	12.0^{de} (142)	69.8	69.5	69.7	4.6	9.9	7.5
Imazethapyr 150 g/ha PoE	10.2^{ab} (104)	9.56^{bcd} (90.7)	9.90^{bc} (97.3)	15.6^{c} (242)	15.1^{c} (226)	15.3^{c} (234)	48.5	51.8	50.1	55.6	53.1	54.4
Imazethapyr + imazamox 70 g/ha PoE (premix)	11.1^{a} (121)	9.98^{bc} (98.7)	10.5^{ab} (110)	18.3^{b} (334)	19.7^{ab} (390)	19.0^{b} (362)	28.9	16.8	22.8	69.8	73.3	71.7
Imazethapyr + imazamox 70 g/ha ePoE (premix) *fb* HW at 40 DAS	9.08^{bc} (82.7)	8.76^{cde} (76.0)	8.92^{cd} (79.3)	12.9^{de} (167)	11.6^{e} (135)	12.3^{d} (151)	64.5	71.2	67.8	18.2	23.8	21.3
Fluazifop-p-butyl + fomesafen 250 g/ha PoE (premix)	10.7^{a} (113)	11.1^{ab} (124)	10.9^{ab} (119)	18.9^{b} (356)	18.8^{b} (355)	18.8^{b} (356)	24.2	24.3	24.1	74.3	73.1	73.7
Fluazifop-p-butyl + fomesafen 250 g/ha ePoE (premix) *fb* IC + HW at 40 DAS	7.57^{d} (57.3)	7.67^{efgh} (58.7)	7.62^{efg} (58.0)	11.4^{e} (130)	11.2^{e} (125)	11.3^{def} (128)	72.3	73.3	72.7	2.8	8.5	6.0
IC *fb* HW at 20 and 40 DAS	6.89^{d} (46.7)	7.80^{efgh} (60.0)	7.35^{efgh} (53.3)	13.8^{cd} (190)	14.0^{cd} (196)	13.9^{c} (193)	59.6	58.2	58.8	1.7	6.5	4.5
Weedy check	11.4^{a} (128)	11.9^{a} (141)	11.6^{a} (134)	21.7^{a} (470)	21.6^{a} (469)	21.6^{a} (469)	-	-	-	89.2	91.3	90.4
F test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	-	-	-	-	-	-
LSD (p=0.05)	8.5	11.0	9.5	7.0	8.7	7.9	-	-	-	-	-	-

Data subjected to $(\sqrt{x+1})$ transformation. Figures in parentheses are means of original values. Treatment means with the letter/ letters in common are not significant by Duncan's New Multiple Range Test at 5% level of significance.

Table 2. Plant stand and plant height as influenced by weed management practices in summer groundnut

Treatment	Plant stand (no./m row length)						Plant height (cm)					
	15 DAS			At harvest			At 30 DAS			At harvest		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Oxyfluorfen 180 g/ha PE *fb* IC + HW at 40 DAS	9.67	9.73	9.70	8.57^{ab}	8.73^{ab}	8.65^{ab}	10.1	7.08^{abc}	8.59	38.6^{d}	38.6^{f}	38.6^{de}
Oxyfluorfen 180 g/ha PE *fb* imazethapyr 100 g/ha PoE	9.33	9.80	9.57	8.17^{abcd}	9.07^{a}	8.62^{abc}	9.67	6.92^{abc}	8.30	41.3^{bcd}	43.0^{bcdef}	42.2^{cd}
Oxyfluorfen 180 g/ha PE *fb* imazethapyr + imazamox 70 g/ha PoE (premix)	10.3	9.53	9.93	9.10^{a}	8.60^{abc}	8.85^{a}	9.44	7.60^{a}	8.52	37.8^{d}	38.2^{f}	38.0^{de}
Quizalofop-ethyl 50 g/ha ePoE *fb* IC + HW at 40 DAS	9.80	9.67	9.73	8.50^{ab}	8.93^{a}	8.72^{ab}	9.03	6.88^{abc}	7.95	36.5^{d}	36.9^{f}	36.7^{e}
Imazethapyr 100 g/ha ePoE *fb* IC + HW at 40 DAS	10.3	9.80	10.1	9.07^{a}	8.80^{a}	8.93^{a}	9.49	7.31^{ab}	8.40	37.6^{d}	37.7^{f}	37.7^{de}
Imazethapyr 150 g/ha PoE	9.67	9.47	9.57	7.03^{cde}	8.40^{abc}	7.72^{bcde}	10.1	6.56^{bc}	8.34	50.7^{a}	52.8^{ab}	51.8^{b}
Imazethapyr + imazamox 70 g/ha PoE (premix)	10.0	9.87	9.93	7.37^{bcde}	6.73^{d}	7.05^{ef}	10.7	6.55^{bc}	8.63	53.5^{a}	59.0^{a}	56.3^{ab}
Imazethapyr + imazamox 70 g/ha ePoE (premix) *fb* HW at 40 DAS	9.67	9.87	9.77	8.40^{abc}	8.80^{a}	8.60^{abcd}	9.13	6.25^{c}	7.69	42.5^{bc}	44.5^{bcde}	43.5^{c}
Fluazifop-p-butyl + fomesafen 250 g/ha PoE (premix)	9.40	9.80	9.60	6.17^{e}	6.67^{d}	6.42^{f}	10.7	6.27^{c}	8.46	43.9^{b}	46.6^{bcd}	45.2^{c}
Fluazifop-p-butyl + fomesafen 250 g/ha ePoE (premix) *fb* IC + HW at 40 DAS	9.00	9.47	9.23	7.93^{abcd}	8.40^{abc}	8.17^{abcd}	9.27	6.67^{bc}	7.97	40.3^{bcd}	41.0^{f}	40.6^{cde}
IC *fb* HW at 20 and 40 DAS	10.0	9.93	9.97	8.87^{a}	8.87^{a}	8.87^{a}	9.53	6.45^{bc}	7.99	43.9^{b}	47.1^{bc}	45.5^{c}
Weedy check	9.33	9.53	9.43	4.37^{f}	4.80^{e}	4.58^{g}	10.4	6.17^{c}	8.27	54.7^{a}	60.8^{a}	57.7^{a}

efficiency with pre-emergence application of oxyfluorfen in groundnut was also reported by Priya *et al.* (2017).

Effect on crop and economics

The lowest plant stand (6.42/m) was observed under weedy check. Application of fluazifop-p-butyl + fomesafen 250 g/ha PoE (pre-mix) and imazethapyr + imazamox 70 g/ha PoE (pre-mix) both were at par with each other but recorded significantly lower plant stand as compared to other herbicidal treatments (**Table 2**). This may be due to phytotoxicity with fluazifop-p-butyl + fomesafen 250 g/ha PoE (pre-mix) and imazethapyr + imazamox 70 g/ha PoE (pre-mix) in terms of necrosis and epinasty and hyponasty symptoms on the leaves. Galon *et al.* (2018) also noted that fluazifop-p-butil + fomesafen caused low (less than 12%) phytotoxicity to the bean. Maximum plant height of 34.8 and 57.7 cm was measured under weedy check at 60 DAS and harvest, respectively. All the herbicidal treatments remained at par with each other with respect to plant height recorded at 60 DAS. At harvest, significantly higher plant height was measured under imazethapyr + imazamox 70 g/ha PoE as compared to rest of the treatment except imazethapyr 150 g/ha PoE. The higher plant height under said treatments may be due to maintenance of weed free environment which leads to better uptake of nutrient by the crops which help in increase in growth of plant in terms of plant height. Shelling percentage was non-significant but seed index was significant only in pooled results (**Table 3**). Significantly higher seed index (37.1 g) was recorded under weedy check as compared to oxyfluorfen 180 g/ha PE *fb* IC + HW at 40 DAS, oxyfluorfen 180 g/ha PE *fb* imazethapyr 100 g/ha PoE, imazethapyr 100 g/ ha PoE *fb* IC + HW at 40 DAS, imazethapyr 150 g/ha PoE and fluazifop-p-butyl + fomesafen 250 g/ha ePoE (pre-mix) *fb* IC + HW at 40 DAS.

Yield reduction in weedy check due to presence of weeds was recorded maximum to the tune of 90.4% followed by fluazifop-p-butyl + fomesafen 250 g/ha PoE (73.7%), imazethapyr + imazamox 70 g/ha PoE (71.7%), imazethapyr 150 g/ha PoE (54.4%) and quizalofop-ethyl 50 g/ha ePoE *fb* IC + HW at 40 DAS. Minimum weed index of 2.00 % was recorded under oxyfluorfen 180 g/ha PE *fb* imazethapyr 100 g/ha PoE. Significantly higher pod yield (3.99 t/ha) was achieved under oxyfluorfen 180 g/ha PE *fb* IC + HW at 40 DAS as compared to quizalofop-ethyl 50 g/ha ePoE *fb* IC + HW at 40 DAS, imazethapyr 150 g/ha PoE, imazethapyr + imazamox 70 g/ha PoE (pre-mix), imazethapyr + imazamox 70 g/ha ePoE (pre-mix) *fb* HW at 40 DAS, fluazifop-p-butyl + fomesafen 250 g/ha PoE (pre-mix) and weedy check (**Table 3**). The higher pod yield under these treatments ascribed due to lower density and dry biomass of weeds prevent the crop-weed competition which facilitate the utilization of available nutrients, moisture, light and space than that of other treatments. These results were in accordance with the results of Priya *et al.* (2017). Further, oxyfluorfen 180 g/ha PE *fb* IC + HW at 40 DAS also recorded significantly higher haulm yield of 5.95 t/ha as compared to quizalofop-ethyl 50 g/ha ePoE *fb* IC + HW at 40 DAS, imazethapyr 150 g/ha PoE,

Table 3. Shelling, seed yield index and yields as influenced by weed management practices in summer groundnut

Treatment	Shelling (%)			Seed index (g)			Pod yield (t/ha)			Haulm yield (t/ha)			Net return (x10^3 ₹/ha)	B:C ratio
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	142.81	3.22
Oxyfluorfen 180 g/ha PE *fb* IC + HW at 40 DAS	66.6	67.2	66.9	33.3	34.8	34.0^{c}	3.51^{a}	4.46^{a}	3.99^{a}	5.36^{a}	6.55^{a}	5.95^{a}	140.23	3.24
Oxyfluorfen 180 g/ha PE *fb* imazethapyr 100 g/ha PoE	66.7	66.6	66.7	33.8	35.3	34.6^{bc}	3.47^{a}	4.35^{a}	3.91^{a}	5.25^{a}	6.34^{ab}	5.80^{a}	132.41	3.09
Oxyfluorfen 180 g/ha PE *fb* imazethapyr + imazamox 70 g/ha PoE (premix)	66.0	66.7	66.4	34.7	36.4	35.6^{abc}	3.42^{a}	4.12^{a}	3.77^{a}	5.11^{a}	6.18^{ab}	5.65^{a}	83.94	2.28
Quizalofop-ethyl 50 g/ha ePoE *fb* IC + HW at 40 DAS	67.2	67.7	67.5	34.8	36.0	35.4^{abc}	2.51^{bc}	3.23^{bc}	2.87^{bc}	4.16^{bc}	5.23^{bcd}	4.70^{bc}	126.63	2.96
Imazethapyr 100 g/ha ePoE *fb* IC + HW at 40 DAS	67.5	67.6	67.5	33.4	34.5	33.9^{c}	3.35^{ab}	4.02^{ab}	3.69^{ab}	4.89^{ab}	5.97^{abc}	5.43^{ab}	35.38	1.58
Imazethapyr 150 g/ha PoE	67.6	67.8	67.7	33.5	34.7	34.1^{c}	1.56^{d}	2.09^{d}	1.82^{d}	2.76^{d}	4.32^{cd}	3.54^{d}	-1.08	0.98
Imazethapyr + imazamox 70 g/ha PoE (premix)	68.6	68.6	68.6	35.7	37.5	36.6^{ab}	1.06^{e}	1.19^{e}	1.13^{e}	1.70^{e}	2.68^{e}	2.19^{e}	97.80	2.50
Imazethapyr + imazamox 70 g/ha ePoE (premix) *fb* HW at 40 DAS	68.4	68.3	68.3	35.5	37.3	36.4^{ab}	2.87^{bc}	3.40^{bc}	3.14^{bc}	4.25^{bc}	5.18^{bcd}	4.71^{bc}	-6.22	0.90
Fluazifop-p-butyl + fomesafen 250 g/ha PoE (premix)	68.5	68.4	68.5	34.4	36.3	35.4^{abc}	0.903^{e}	1.20^{e}	1.05^{e}	1.23^{ef}	2.07^{e}	1.65^{e}	129.51	2.99
Fluazifop-p-butyl + fomesafen 250 g/ha ePoE (premix) *fb* IC + HW at 40 DAS	66.9	67.0	67.0	34.0	35.8	34.9^{bc}	3.41^{a}	4.08^{a}	3.75^{a}	5.03^{a}	6.08^{ab}	5.55^{a}	127.94	2.86
IC *fb* HW at 20 and 40 DAS	68.6	68.5	68.5	34.3	36.1	35.2^{abc}	3.45^{a}	4.17^{a}	3.81^{a}	5.37^{a}	6.32^{ab}	5.84^{a}	-37.31	0.36
Weedy check	67.4	67.0	67.2	36.0	38.2	37.1^{a}	0.380^{f}	0.39^{f}	0.385^{f}	0.793^{f}	1.02^{f}	0.905^{f}	35.38	-
F test	NS	NS	NS	NS	NS	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	-	-
LSD (p=0.05)	3.3	3.2	3.2	3.3	6.1	4.97	10.1	11.4	10.9	10.1	12.9	12.0	-	-

Data subjected to ($\sqrt{x+1}$) transformation. Figures in parentheses are means of original values. Treatment means with the letter/ letters in common are not significant by Duncan's New Multiple Range Test at 5% level of significance.

imazethapyr + imazamox 70 g/ha PoE (pre-mix), imazethapyr + imazamox 70 g/ha ePoE (pre-mix) *fb* HW at 40 DAS, fluazifop-p-butyl + fomesafen 250 g/ha PoE (pre-mix). Application of oxyfluorfen as pre-emergence controlled broad-spectrum of weeds during initial stage of crop and later germinated weeds was manage by hand weeding and intercultivation which provide congenial environment for growth and development of the crop for a longer period which lead to improvement in yield of crop. Among different weed management practices, pre-emergence oxyfluorfen 180 g/ha PE *fb* IC + HW at 40 DAS was recorded higher net return (₹ 2,02,799/ha) followed by oxyfluorfen 180 g/ha PE *fb* imazethapyr 100 g/ha PoE. However, benefit cost ratio, of 3.24 and 3.22 were achieved under pre-emergence application of oxyfluorfen 180 g/ha PE *fb* imazethapyr 100 g/ha PoE and oxyfluorfen 180 g/ha PE *fb* IC + HW at 40 DAS, respectively. Further, IC *fb* HW at 20 and 40 DAS recorded lower BC ratio might be due to higher additional cost of cultivation.

Conclusion

In nutshell, pre-emergence application of oxyfluorfen 180 g/ha PE *fb* interculturing (IC) + hand weeding (HW) at 40 DAS effectively managed the weeds and also recorded higher pod yield, net return and B:C ratio followed by oxyfluorfen 180 g/ha PE *fb* imazethapyr 100 g/ha PoE, IC *fb* HW at 20 and 40 DAS, oxyfluorfen 180 g/ha PE *fb* imazethapyr + imazamox 70 g/ha PoE (pre-mix) and fluazifop-p-butyl + fomesafen 250 g/ha ePoE (pre-mix) *fb* IC + HW at 40 DAS.

REFERENCES

Chandolia PC, Dadheech RC Solanki NS and Mundra SL. 2010. Weed management in groundnut (*Arachis hypogaea* L.) under varying crop geometry. *Indian Journal of Weed Science* **42**(3&4): 235–237.

Cochran WG and Cox GM. 1957. Experimental Designs, John Willey and Sons. Inc., New York.

Galon L, Castoldi CT, Forte CT, De David FA, Perin GF and Radunz AL. 2018. Weed management in beans using sub doses of fluazifop-p-butyl + fomesafen. *PlantaDaninha* **36**: 1–13.

Jat RS, Meena HN, Singh AL, Surya MJ and Mishra JB. 2011. Weed management in groundnut in India- A review. *Agriculture Reviews* **32**(3): 155–171.

Kumar V and Gill GS. 1969. Weed index a new method for reporting weed control traits. *Indian Journal of Agronomy* **6**(2): 96–98.

Maity SK and Mukherjee PK. 2011.Effect of brown manuring on grain yield and nutrient use efficiency in dry direct seeded *Kharif* rice. *Indian Journal of Weed Science* **43**(1&2): 61–66.

Priya RS, Chinnusamy C, Murali Arthanari P, Janaki P and Babu C. 2017. Evaluation of Oxyfluorfen (23.5% EC) Herbicide on Weed Control, Economics and Profitability of Groundnut in the Western Zone of Tamil Nadu. *Chemical Science Review and Letters* **6**(21): 88–93.

Sameer L, Gurikar R and Kulkarni GN. 2014. Production and Export of Ground nut from India - An Overview. *International Research Journal of Agricultural Economics and Statistics* **5**: 293–298.

Indian Journal of Weed Science **52**(3): 254–258, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Weed flora dynamics and yield of mustard as influenced by tillage and weed management in pearlmillet-mustard-cowpea cropping system

Varsha Gupta*, D.S. Sasode, Ekta Joshi, Sushma Tiwari and Y.K. Singh

Rajmata Vijyaraje Scindia Krishi Vishva Vidyalaya, Gwalior, Madhya Pradesh 474 002, India

**Email: drvarshagupta11@gmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00049.0

Type of article: Research article

Received : 30 April 2020
Revised : 18 August 2020
Accepted : 1 September 2020

Key words

Conservation tillage

Mustard

Productivity

Weed flora

Weed management

ABSTRACT

The effects of tillage and weed management practices were evaluated for four years (2014-15 to 2017-18) in pearlmillet-mustard-cowpea cropping system. The results revealed that conventional tillage during *Kharif* (rainy) and *Rabi* (winter) seasons and zero tillage with previous crop residue application significantly increased the grain yield by 36 and 15% and reduced the total weed biomass by 57 and 26%, respectively compared to zero tillage without residue application. Among different weed flora, conventional tillage during *Kharif* and *Rabi* season *fb* the zero tillage with previous crop residue reduced the population of *P. minor* by 24.6 and 16%, *C. arvensis* and *M. hispida* by 50 and 29% and *C. rotundus* by 42 and 10% with weed control efficiency of 79 and 65%, respectively at 60 DAS over zero tillage without residue application. However, among different weed management practices, the pre-emergence application of oxyfluorfen 0.23 kg/ha with one hand weeding at 30-35 DAS resulted in significant reduction of total weed biomass, highest grain yield, weed control efficiency and net returns. The integrated weed management approach reduced the narrow-leaved weeds by 75%, broad-leaved weeds by 86% and sedges by 90% as compared to the weedy check.

INTRODUCTION

Among oilseeds, mustard occupies second position after soybean in India. It is cultivated in 5.96 mha area with the annual production of 8.32 mt and average productivity of 1.39 t/ha. In Madhya Pradesh, the area occupied under rapeseed and mustard is 0.75 mha with the annual production 0.98 mt and average productivity of 1.30 t/ha (Anonymous 2018). Pearlmillet-mustard is a very popular cropping system in the gird zone of Madhya Pradesh.

Conservation agriculture (CA) practice involves minimum soil disturbance with residue management for achieving higher productivity (Bhan and Behera 2014). CA based crop management technologies are more efficient, improve production and income and address the emerging problems (Gupta and Seth 2007). The presence of crop residue on the soil surface may influence soil temperature and moisture regimes that affect weed seed germination and it helps in reducing weed growth through reduced weed emergence (Sharma *et al.* 2013) and increase the crop yield. Zero tillage (ZT) based crop production can reduce input costs and labour, and conserve the soil (Busari *et al.* 2015). Weed species shifts and losses in crop yield as a result of increased weed density have been cited as major hurdles to the widespread adoption of CA. The presence of crop residue on the soil surface may influence soil temperature and moisture regimes that affect weed emergence patterns over the growing season. Under conventional and conservation tillage practices, crop yields may be similar if crop stands are uniform and weeds are managed under threshold levels. If weeds are not controlled during critical periods of crop-weed competition, the yields of mustard crop may reduce drastically up to 58% (Banga and Yadav 2001). The findings of weed species shifts under CA have however, been largely inconsistent (Chauhan *et al.* 2006). Several studies have been indicated that the density of perennial weeds increased in CA (Malik *et al.* 2002). Meanwhile, the use of different weed control strategies in CA system could influence weed population and density conspicuously over a period of time (Muoni *et al.* 2016).

Research efforts so far indicate that no single practice of weed management is economically effective for a given crop or cropping system. Surface residue retention in ZT suppresses weed emergence to a certain extent and also restricts mechanical or manual weed control (Mhlanga *et al.* 2016). Meanwhile, hand weeding has been a traditional and effective but economically unfeasible method of weed control in mustard. So, it is imperative to find out the alternative methods for reducing the weed density during early growth period of crops to realize maximum yields. Thus, weed management with herbicides by integration of tillage practices may increase the productivity of crops by decreasing the weed density and nutrient removal by the weeds.

MATERIALS AND METHODS

A field experiment was conducted during *Rabi* 2014-15 to 2017-18 to study the weed flora dynamics, growth and yield response of mustard crop as influenced by conservation tillage and weed management practices in pearlmillet–mustard–cowpea cropping system at Research Farm, College of Agriculture, RVSKVV, Gwalior (79° 54' E longitude and 23° 10' N latitude, 412 above MSL), Madhya Pradesh, The average rainfall of gird zone was 750 mm and very little and occasional rains were received during the crop growth period in four years. Humidity ranged from 93% in the morning to 28% in the evening and temperature ranged from 4°C to 32°C. The soil was low in nitrogen content (246 kg/ha), medium in phosphorus (13.0 kg/ha) and potassium (243 kg/ha) with sandy clay loam in texture. The pH of the soil was 7.6 with electrical conductivity 0.34 S/m containing 0.5% organic carbon in the topmost layer up to 15 cm of the soil. The experiment was laid out in a strip plot design, replicated thrice and consisted of 15 treatments. The five treatments of tillage practices were conventional tillage in *Kharif* and *Rabi* both and fallow in summer; conventional tillage in *Kharif fb* zero tillage in *Rabi* and summer both; zero tillage in *Kharif*, *Rabi* and summer, zero tillage in both *Kharif* and summer and with crop residues in *Rabi*, zero tillage with crop residues in *Kharif, Rabi* and summer in combination with three weed management practices, *viz.* pendimethalin 1.0 kg/ha just after sowing as PE, oxyfluorfen 0.23 kg/ha just after sowing as PE *fb* one hand weeding at 25-30 DAS and one kept weedy check for comparison. Two ploughing was done by the cultivator *fb* rotavator, 15 cm deep in the plots where conventional tillage (CT) was done *fb* levelling before sowing of the crop. The soil was not disturbed where ZT was done.

The recommended dose of NPK for mustard (80:40:20 kg/ha) was applied. The variety '*Rohini'* was sown 6 kg/ha in rows 40 cm apart and later thinning was done to maintain plant to plant distance as 10 cm. Before sowing, the seeds were treated with the fungicides dithane M-45 2.0 g/kg seed, for 30 minutes to control soil and seed borne diseases. Crop residues were placed as per the treatments and irrigation was applied as per requirement of crop during the experimentation. Herbicides were applied as per the treatments with the help of knapsack sprayer and flat-fan nozzle of spray volume 500 litres water/ha. Weed observations were recorded with the help of a quadrate 1.0 m^2 placed randomly at two spots in each plot at 30 and 60 DAS. The number of weed species present in the quadrate was recorded, sun dried for a few days then oven dried at 75°C for 48 hours, weighed and expressed in g/m^2. Weed control efficiency was calculated using weed dry weight at 60 DAS and economics of different weed control treatments was worked out by taking the selling price of mustard at existing market prices of the inputs. Statistical analysis of the data was carried out using ANOVA technique as applicable to strip plot design. The data on weed density was subjected to square root transformation *i.e.* $\sqrt{x+0.5}$ before carrying out analysis of variance and comparisons were made on transformed values only.

RESULTS AND DISCUSSION

Soil parameters

After completion of the first phase of long-term experimentation in four years, available nitrogen in the soil was decreased 4% (237 kg/ha) while the available phosphorous and potassium was increased by 46% (19.7 kg/ha) and 14% (277 kg/ha), respectively. However, the organic carbon of the soil was increased from 0.4 to 0.5 and pH from 7.6 to 7.8, but the electrical conductivity was remained same (0.34 dS/m) in the soil.

Weed flora

The major weed flora observed in an experimental site during the four years (2014-15 to 2017-18) at 30 and 60 DAS as influenced by different tillage and weed management practices were presented (**Table 1**). The main weeds were *Phalaris minor* (7%), *Spergula arvensis* (10%), and *Cynodon dactylon* (8%) as grasses and *Chenopodium album* (13%), *Anagallis arvensis* (18%), *Convolvulus arvensis* (8%), and *Medicago hispida* (6%) as major broad-leaved weeds. *Cyperus rotundus* (30%) was most dominating sedges among all the weeds grown in the experimental site. In the beginning of the experimentation, density of *Cynodon dactylon* and *Medicago hispida* was very less (2014-15 and 2015-

16) but the density and weed biomass of other weeds increased with time and thereafter declined.

Among different tillage practices **(Table 1**), density of *C. rotundus* was maximum over *P. minor*, *S. arvensis* and *C. dactylon*, whereas the maximum density of broad-leaved weeds was found in *A. arvensis fb C. album.* The count of *M. hispida* was very less during the entire crop growth period in four years.

Effect on weeds

All the weed control treatments proved effective in reducing the population and dry weight of weeds over weedy check (**Table 1**). Under different conservation tillage practices, conventional tillage during *Kharif* and *Rabi* both resulted significant reduction in weed population and relative weed dry weight with 79% weed control efficiency *fb* ZT practice with residue application during *Kharif* and *Rabi* and without residues in summer with 65% WCE due to fragile seedbed and better aeration which favour the germination and better growth of crop. Similarly, the population of *P. minor* as narrow-leaved weed, *C. arvensis* and *M. hispida* as broad-leaved weeds significantly reduced but the population of *Cyperus rotundus* was much higher under ZT without residue application in all three seasons compared to CT during both *Kharif* and *Rabi* season. Among different weed flora, CT during both *Kharif* and *Rabi* season and ZT with residues application in *Kharif* and *Rabi* and without residue in summer reduced the population of *P. minor* by 85 and 62% and broad-leaved weeds by 23 and 8%, respectively. The influence of tillage treatments was not seen on sedges but the population of *P. minor* and *S. arvensis* continued to be less from 30 to 60 DAS (**Table 1**). Therefore, CA, can contribute to decrease the population of *P. minor* and *S. arvensis* in mustard.

Under different weed management practices, higher weed population and dry weight was recorded in weedy check while the lowest was recorded with integrated weed management practices where pre-emergence oxyfluorfen 0.23 kg/ha with one hand weeding at 25-30 DAS was applied. The weed control efficiency was also 86% which was 12% higher over pre-emergence application of pendimethalin 1.0 kg/ha alone.

Effect on crop

Tillage and weed control practice exerted significant effect on plant height, number of branches/plants, length of siliqua, number of siliquae/ plant and number of seeds/siliqua. The crop stands were uniform in the field under CT practice during *Kharif* and *Rabi* which resulted in significant increase in the yield and growth parameters of mustard crop (**Table 2**). Similar study was done by Yaduraju *et al.* (2002) and Mishra *et al.* (2005). The maximum seed yield was recorded 1.96 t/ha which was 19% higher than ZT without crop residue **(Table 3**).

Table 1. Density of different weeds/m², WCE and weed biomass as affected by different tillage and weed management practices in mustard under pearl millet-mustard-cowpea cropping system (pooled 2014-15 to 2017-18)

Treatment	Narrow-leaved weeds/m²								Broad-leaved weeds/m²								WCE %	Weed biomass (kg/ha)
	C. rotundus		*P. minor*		*S. arvensis*		*C. dactylon*		*M. hispida*		*C. album*		*A. arvensis*		*C. arvensis*			
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	60 DAS	at harvest
Tillage practice																		
CT-CT-F	5.76	7.13	1.44	1.34	1.58	1.66	1.97	2.47	1.37	1.42	2.36	3.26	2.93	3.49	1.87	2.17		
	(40.7)	(53.2)	(2.9)	(1.9)	(3.9)	(3.2)	(4.4)	(7.3)	(1.9)	(2.4)	(8.9)	(14.5)	(17.1)	(19.8)	(3.8)	(5.6)	79.33	235
CT-ZT-ZT	8.11	9.08	1.99	1.59	3.14	2.14	2.77	3.07	1.75	1.99	4.08	4.69	6.10	5.81	2.62	2.64		
	(88.8)	(91.6)	(7.9)	(2.8)	(22.3)	(6.6)	(10.3)	(11.7)	(3.9)	(5.2)	(31.4)	(33.2)	(60.2)	(62.6)	(9.2)	(9.0)	50.81	288
ZT-ZT-ZT	8.60	9.89	1.81	1.83	2.93	2.55	2.39	3.23	1.86	2.09	4.12	5.29	7.10	6.85	2.81	3.50		
	(102.5)	(118.1)	(3.8)	(3.9)	(18.6)	(9.2)	(6.9)	(11.8)	(4.6)	(5.2)	(32.4)	(42.4)	(95.7)	(85.4)	(10.2)	(14.0)	27.20	368
ZT-ZT+R–ZT	8.71	9.06	1.97	1.67	2.50	2.48	2.21	2.69	1.60	2.05	4.22	4.23	5.57	5.74	2.47	2.48		
	(90.4)	(99.5)	(7.7)	(3.5)	(13.7)	(8.4)	(6.4)	(8.6)	(3.7)	(5.4)	(35.4)	(25.0)	(60.5)	(51.2)	(8.4)	(7.3)	43.95	324
ZT+R-ZT+R–ZT	7.40	9.92	1.36	1.76	1.98	2.02	2.13	2.64	1.58	1.52	2.93	3.75	3.15	3.69	2.44	2.68		
	(74.5)	(109.4)	(1.9)	(3.4)	(6.7)	(5.6)	(5.7)	(8.1)	(3.2)	(2.4)	(14.4)	(19.3)	(18.4)	(20.2)	(8.4)	(9.1)	64.85	292
LSD (p=0.05)	0.79	0.82	0.24	0.32	0.48	0.46	0.38	0.42	0.18	0.40	0.53	0.43	0.74	0.73	0.36	0.39	-	57
Weed management																		
Pendimethalin	7.46	8.16	1.03	1.40	1.50	1.59	2.23	2.53	1.35	1.54	1.92	3.02	2.99	3.33	2.27	2.31		
	(63.1)	(72.3)	(0.8)	(2.1)	(2.8)	(3.1)	(5.1)	(6.6)	(1.8)	(2.8)	(4.9)	(14.3)	(11.2)	(13.0)	(5.3)	(6.0)	73.57	325
Oxyfluorfen +	4.13	6.42	0.77	0.94	0.71	1.33	0.87	1.78	0.71	1.16	0.87	2.31	0.86	1.45	1.05	1.83		
1 HW	(27.6)	(42.7)	(0.2)	(0.6)	(0.0)	(2.1)	(0.4)	(3.8)	(0.0)	(1.3)	(0.5)	(7.7)	(0.6)	(2.7)	(0.9)	(3.8)	86.11	133
Weedy check	11.56	12.47	3.34	2.58	5.07	3.59	3.78	4.15	2.84	2.74	7.83	7.40	11.06	10.56	4.00	3.94		
	(152.2)	(168.1)	(13.6)	(6.6)	(36.3)	(14.6)	(14.7)	(18.2)	(8.6)	(8.2)	(68.1)	(58.6)	(139.4)	(127.8)	(17.8)	(17.2)	-	445
LSD (p=0.05)	0.67	0.74	0.24	0.32	0.41	0.25	0.28	0.34	0.18	0.29	0.38	0.36	0.51	0.67	0.26	0.43	-	49
Interaction	Sig	Sig	Sig	NS	Sig	Sig	NS	NS	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	-	NS

CA: Conventional tillage, ZT: Zero tillage, F: fallow, R: Residue

Among ZT practices, the highest seed was yielded from the ZT with crop residue in *Kharif* and *Rabi* both and without residue in summer which was 15% higher compared to ZT without residue. ZT with residue as mulch on the soil surface may influence soil temperature and moisture regimes that affect weed seed germination and emergence patterns over the growing season thus help in greater suppression ability of weeds than the without residue treatments that indirectly led to better growth and yield of mustard. The ZT without residue application resulted in the lowest values of growth and yield attributes of mustard. ZT with residue application during *Rabi* only and both *Kharif* and *Rabi* increased the grain yield by 10 and 15%, respectively compared to ZT without residue application. The higher growth and yield of mustard in ZT with residue application may be attributed to better aeration and adequate moisture or differences in soil structure and fertility level.

Integrated weed management application where pre-emergence oxyfluorfen 0.23 kg/ha with one hand weeding at 25-30 DAS was done, resulted in the significantly higher values of growth and yield attributes compared to all other treatments and was *fb* the pre-emergence application of pendimethalin 1.0 kg/ha alone. Application of oxyfluorfen 0.23 kg/ha + one hand weeding at 25-30 DAS established its superiority by recording significantly higher grain yield (**Table 3**) and noted the increment by 34.7 and 19% of seed and stover yield compared to weedy check and 24.6 and 9% higher seed and stover yield in pre-emergence application of pendimethalin 1.0 kg/ha respectively. This increase in yield might be due to effective control of weeds in early stage, which smothered weed growth and gave higher yield attributes of mustard and ultimately resulted to higher yields. The results are in conformity with the findings of Sasode *et al.* (2020) and Radhey Shyam *et al.* (2014).

Economics

Among different tillage practices, CT during both *Kharif* and *Rabi* season and ZT with crop residue during *Kharif* and *Rabi* and without residue in summer season increased the net monetary returns by 58 and 27% and B:C ratio by 24 and 18%, respectively compared to ZT without residue application (**Table 3**). Among different weed management practices, the application of pendimethalin 1.0 kg/ha alone recorded significantly higher B:C ratio (3.21) but net monetary returns were recorded higher (₹ 45747/ha) with the application of oxyflourfen + one hand weeding at 25-30 DAS. However, the net monetary returns (₹ 40709/ha) and benefit cost ratio (2.87) were lowest in weedy check plots.

Based on four years experimentation it is concluded that the population of *P. minor* as narrow and *C. arvensis* and *M. hispida* as broad-leaved weeds continues to be less under CT during *Kharif* and *Rabi* both *fb* the ZT with crop residue application during *Kharif* and *Rabi* and without residue in summer. The application of oxyflourfen 0.23kg/ha with one hand weeding at 25-30 DAS resulted in the maximum control of weeds and provided the maximum grain yield and net returns under conventional tillage during *Kharif* and *Rabi.* Therefore, CT, can contribute to decrease narrow-leaved weeds and higher productivity and profitability of mustard in pearlmillet-mustard-cowpea cropping system.

Table 2. Growth of the mustard crop as affected by different tillage and weed management practices under pearlmillet-mustard-cowpea cropping system at harvest stage (pooled 2014-15 to 2017-18)

Treatment	Plant height (cm)	No. of branches/plant	Length of siliqua (cm)	No. of siliqua /plant	No. of seeds/ siliqua
Tillage practice					
CT-CT-F	162	5.32	4.48	203.4	14.2
CT-ZT-ZT	154	4.69	4.34	190.0	13.5
ZT-ZT-ZT	151	4.52	4.22	175.8	13.2
ZT-ZT+R–ZT	152	4.62	4.33	182.0	13.6
ZT+R-ZT+R–ZT	155	4.87	4.35	190.3	13.7
LSD (p=0.05)	4.6	0.36	0.10	10.6	0.40
Weed management					
Pendimethalin	156	4.85	4.32	190.5	13.8
Oxyfluorfen + 1 HW	163	5.55	4.62	210.4	14.4
Weedy check	145	4.01	4.09	163.9	12.6
LSD (p=0.05)	2.4	0.18	0.08	5.90	0.27
Interaction	NS	Sig	NS	Sig	NS

CA: Conventional tillage, ZT: Zero tillage, F: fallow, R: Residue

Table 3. Yield and economics of the mustard crop as affected by different tillage and weed management practices under pearlmillet-mustard-cowpea cropping system at harvest stage (pooled 2014-15 to 2017-18)

Treatment	Seed yield (t/ha)					Stover yield (t/ha)					Net returns (x10^3 ₹/ha)					B:C ratio
	2014-15	2015-16	2016-17	2017-18	Pooled	2014-15	2015-16	2016-17	2017-18	Pooled	2014-15	2015-16	2016-17	2017-18	Pooled	
Tillage practice																
CT-CT-F	1.98	1.95	1.96	1.97	1.96	7.12	6.54	5.70	7.96	6.83	51.07	49.79	50.34	50.52	50.43	3.45
CT-ZT-ZT	1.64	1.62	1.58	1.68	1.63	6.05	6.49	5.60	6.94	6.27	41.83	37.61	38.26	41.18	39.72	3.24
ZT-ZT-ZT	1.46	1.42	1.35	1.53	1.44	5.81	5.25	4.58	6.48	5.53	32.88	31.01	28.64	35.26	31.95	2.80
ZT-ZT+R–ZT	1.57	1.60	1.47	1.70	1.58	6.46	5.47	5.24	6.69	5.96	39.95	35.68	33.88	41.75	37.82	3.14
ZT+R-ZT+R–ZT	1.69	1.62	1.66	1.65	1.65	6.57	5.56	5.44	6.68	6.06	46.37	34.96	41.39	39.94	40.67	3.30
LSD (p=0.05)	0.08	0.11	0.21	0.10	0.11	0.19	0.51	0.86	0.81	0.54	4.58	4.27	4.32	3.93	4.87	0.15
Weed management																
Pendimethalin	1.70	1.75	1.67	1.78	1.72	5.84	6.38	5.26	6.96	6.11	43.13	40.97	40.39	43.71	42.05	3.21
Oxyfluorfen + 1 HW	1.88	1.85	1.81	1.92	1.86	6.58	6.76	5.98	7.37	6.67	47.25	44.25	44.26	47.23	45.75	3.16
Weedy check	1.40	1.35	1.33	1.42	1.38	5.06	6.16	4.70	6.53	5.61	31.17	30.25	29.04	32.38	30.71	2.87
LSD (p=0.05)	0.04	0.03	0.21	0.07	0.11	0.19	0.37	0.47	1.08	0.46	4.12	4.22	3.96	3.23	4.90	0.15
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

CA: Conventional tillage, ZT: Zero tillage, F: fallow, R: Residue

REFERENCES

Anonymous 2018. *Agriculture Statistics at a Glance*. Department of Agriculture, Cooperation & Farmers Welfare, *GOI*.

Banga RS and Yadav A. 2001. Evaluation of herbicides against complex weed flora in Indian mustard. *Haryana Journal of Agronomy* **17**: 48–51.

Bhan M and Kewat ML. 2003. Activity and persistence of pendimethalin applied pre-emergence to soybean in Vertisol. *Annals of Agricultural Research* **24**(4): 970–972.

Bhan S and Behra UK. 2014. Conservation agriculture in India – Problems, prospects and policy issues. *International Soil and Water Conservation Research* **2**(4): 1–12.

Busari MA, Kukal SS, Kaur A, Bhatt R and Dulazi AA. 2015. Conservation tillage impacts on soil, crop and the environment. *International Soil and Water Conservation Research* **3**(2): 119–129.

Chauhan BS, Gill G, Preston C. 2006. Seedling recruitment pattern and depth of recruitment of 10 weed species in minimum tillage and no-till seeding systems. *Weed Science* **54**(4): 658–668.

Gupta RK and Seth A. 2007. A review of resource conserving technologies for sustainable management of the rice-wheat cropping systems of the Indo-Gangetic Plains (IGP). *Crop Protection* **26**: 436–447.

Hossain M, Begum M, Hashem A, Rahman M, Bell RW, Haque ME. 2014. Yield response of mustard as influenced by weed management practice under conservation agriculture system. *Bangladesh Journal of Weed Science* **4&5**: 87–92.

Malik R, Yadav A, Singh S, Malik R, Balyan R, Banga R, Sardana P, Jaipal S, Hobbs PR and Gill G. 2002. A success story: Herbicide resistance management and evolution of zero tillage. *Research Bulletin* 1–43.

Mhlanga B, Cheesman S, Chauhan BS, Thierfelder C. 2016. Weed emergence affected by maize (*Zea mays* L.)-cover crop rotations in contrasting arable soils of Zimbabwe under conservation agriculture. *Crop Protection* **81**: 47–56.

Mishra JS and Singh VP. 2005. Effect of tillage and weed control methods on weeds and yield of rice-wheat and soybean-wheat cropping systems. *Indian Journal of Weed Science* **37**(3&4): 251–253.

Muoni T, Rusinamhodzi L, Rugare JT, Mabasa S, Mangosho E, Mupangwa W and Thierfelder C. 2016. Effect of herbicide application of 10 weed species in minimum tillage and no-till seeding systems. *Weed Science* **54**: 658–668.

Sasode DS, Joshi E, Jinger D, Sasode RS, Gupta V and Singh YK. 2020. Conservation tillage and weed management practices effect on weeds, yield and profitability of cowpea (*Vigna* unguiculata). *Indian Journal of Agricultural Sciences* **90**(1): 86–90.

Sharma AR, Singh VP and Singh R. 2013. Weed management in conservation agriculture systems-problems and prospects. pp. 31–42. In: *Proceedings 24th Asian-Pacific Weed Science Society Conference,* October 22-25, 2013, Bandung, Indonesia.

Sharma SN. 2012. Innovations in field experiments-*Planning and statistical analysis*. Publishers: Jain Brothers.

Shyam R, Singh R and Singh VK. 2014. Effect of tillage and weed management practices on weed dynamics, weed seed bank and grain yield of wheat in rice-wheat system. *Indian Journal of Weed Science* **46**(4): 322–325.

Yaduraju NT and Mishra JS. 2002. Zero-Tillage in rice–wheat cropping system on vertisols in Madhya Pradesh—prospects and problems. pp. 117–119. In: *Proceedings of International Workshop on Herbicide Resistance Management and Zero-Tillage in Rice–Wheat Cropping system.* March 4–6, 2002. CCSHAU, Hisar India.

Indian Journal of Weed Science **52**(3): 259–264, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Herbicide resistance in *Rumex dentatus* against metsulfuron herbicide in Punjab and Haryana, India

Sachin Dhanda*, Ankur Chaudhary[1], Simerjeet Kaur and Makhan S. Bhullar

Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab 141 004, India

[1]CCS HAU Regional Research Station, Uchani, Haryana 132 001, India

**Email: sachin-agr@pau.edu*

Article information

DOI: 10.5958/0974-8164.2020.00050.7

Type of article: Research article

Received : 16 May 2020

Revised : 15 September 2020

Accepted : 21 September 2020

Key words

Herbicide resistance

Metsulfuron-methyl

Rumex dentatus

Wheat

ABSTRACT

Over-reliance and continuous use of similar mode of herbicides lead to increase in selection pressure which resulted in evolution of herbicide resistance in weeds. Metsulfuron-methyl is used for the control of broad-leaf weeds in wheat since 1990s. There are reports of failure of control of *Rumex dentatus* with metsulfuron from farmers' fields in North-Western India. Pot studies were conducted at Punjab Agricultural University, Ludhiana during winter *(Rabi)* 2018-19 and 2019-20 to quantify the status and level of herbicide resistance in *R. dentatus* in Punjab and Haryana. *Rumex* populations were collected from farmers' fields in both years. Fifty six and 33 biotypes of *R. dentatus* from farmers' fields of Haryana and 6 and 19 biotypes from Punjab were collected in first and second year, respectively. Biotypes were screened using recommended dose of metsulfuron-methyl (5 g/ha) along with unsprayed in pot study. Results revealed that 38 out of 56 biotypes of *R. dentatus* collected from Haryana in first year were found resistant to metsulfuron whereas only one biotype showed resistance from Punjab. Further, 23 biotypes out of 33 biotypes collected in second year were found resistant from Haryana whereas 14 biotypes out of 19 were found resistant in Punjab. This indicated that *R. dentatus* has evolved resistance against metsulfuron-methyl in different regions of Punjab and Haryana.

INTRODUCTION

Wheat is the second most important food crop after rice in India with 99.78 mt production from 30.59 mha area and having productivity of 3.22 t/ha (Anonymous 2018). Punjab and Haryana states contribute 65% for wheat in central pool and recognized as food bowl for national food security. Weeds are the major biological constraints that halt potential productivity of wheat crop by competing for natural resources and impairing the quality of produce (Chhokar *et al.* 2012). The yield losses in wheat due to weed competition could be reached up to 60% (Rao *et al.* 2014) and also the complete failure under severe competition with resistant weed species (Malik and Singh 1995). The problem of broad-leaf weeds is emerging in areas where herbicides for controlling grass weeds are continuously being applied without supplementing with broad-leaf weed herbicides (Chhokar *et al.* 2015).

Rumex dentatus L. (toothed dock/ Jangli palak) is the dominant broad-leaf weed of wheat in rice-wheat cropping system. It is an annual plant of polygonaceae family having 30-70 cm long erect stem with branching habit from base. It is having long emergence period, comparatively faster growth, and higher fecundity. Wheat is more prone to *R. dentatus* competition as compared to *Phalaris minor* because of its high biomass and fast growth than wheat (Singh *et al.* 2013, Singh 2012). The losses in the crop grain yield increased from 1.3% to 69.8% when density of *R. dentatus* increased from 5 to 30 plants/m^2 (Waheed *et al.* 2017). Metsulfuron was recommended at very low dose rate (2-4 g/ha) for weed control in wheat during 1988 that provided satisfactory control of *R. dentatus* and other broad-leaf weeds. Metsulfuron, a sulfonylurea herbicide is an ALS inhibitor, which inhibit the activity of acetolactate synthase enzyme which is required for the synthesis of branched chain amino acids namely isoleucine, valine and leucine. It caused the starvation of plants for these three amino acids (Whitcomb 1999). Therefore, disruption of protein synthesis and photosynthates transport resulted in death of susceptible biotype. But in resistant biotypes, plants develop mechanism to nullify the effect of herbicide. The mechanism of herbicide resistance may be due to either target-site (altered site of action or over-expression of gene) or non-target site (reduction in amount of herbicide that reaches the target site via reduced uptake or translocation of herbicide, increased metabolism of herbicide, herbicide sequestration and/or decreased rate of herbicide activation) herbicide resistance (Powles and Yu 2010). Due to continuous use of Metsulfuron-methyl, evolution of herbicide resistance in *R. dentatus* against this herbicide in Panipat region of Haryana was reported (Chhokar *et al.* 2013). Moreover, this resistant biotype showed cross resistance to iodosulfuron, triasulfuron, florasulam, iodosulfuron-methyl-sodium, mesosulfuron-methyl, halauxifen + florasulam and pyroxsulam (Chhokar *et al.* 2018). In India, it was the first case of herbicide resistance in broad-leaf weeds and first case in *R. dentatus* globally. So, the present study was conducted to confirm the status and level of the resistance at farmers' fields in two adjoining states namely Punjab and Haryana, India.

MATERIALS AND METHODS

Survey was conducted at the end of wheat growing season in the months of March and April in 2018 and 2019 from the rice-wheat grown regions of Haryana and Punjab. The wheat fields were selected based on the reports of weed control failures from farmers' fields. The seeds of *R. dentatus* populations that survived after recommended dose of herbicide application or escaped even after the herbicide application was collected. The seeds were collected from the fields at least 20 to 30 feet inside the field edge to make sure that the putative resistant plants were treated with herbicide application. The seeds were threshed and placed in paper bags. Bags were marked with name of village and district along with their GPS location. During first year survey, total 56 biotypes of *R. dentatus* were collected from Haryana state comprising Kaithal (8), Kurukshetra (11), Karnal (14), Ambala (8), Panchkula (2), Panipat (3), Yamunanagar (5) and Jind (5). Only six biotypes were collected from Punjab comprising Jalandhar (1), Ludhiana (1), Barnala (2) and Sangrur (2) districts, where farmers reported poor weed control. In second year, the study was extended further and 52 biotypes were again collected from different regions of both the states. A total of 33 biotypes were collected from Haryana state comprising Panipat (2), Jind (4), Kaithal (4), Karnal (5), Kurukshetra (3), Ambala (4), Yamunanagar (2), Rohtak (2), Bhiwani (2), Hisar (1), Fatehabad (2) and Sirsa (2) districts. A total of 19 biotypes were collected from Punjab, covering Fatehgarh Sahib (2), Hoshiarpur (1), Ludhiana (2), Mohali (2), Patiala (3), Rupnagar (1), Saheed Bhagat Singh Nagar (3), Barnala (2), Abohar (1) and Sangrur (2) districts.

The study was conducted at Punjab Agricultural University, Ludhiana during winter *(Rabi)* 2018-19 and 2019-20. The experiment was carried out in completely randomized design (CRD) with six replications. For pot study, soil was taken from the Students' Research Farm area which was free from weeds and was not exposed to any herbicides from the last three years for filling the pots. The soil was first air dried followed by fine crushing and finally passed through a 2 mm sieve. Earthen pots with 25 cm diameter were filled with the mixture of sand, field soil and vermi-compost in the ratio of 2:3:1. The pots were properly watered before sowing and the weeds were allowed to germinate, which were uprooted regularly for a month to exhaust the weed seed bank of soil. All the *R. dentatus* biotypes were sown in the pots on 21 October 2018 and 24 October 2019 for winter 2018-19 and 2019-20, respectively. Twenty seeds of each biotype were sown per pot at a depth of 2-3 cm and pots were lightly watered just after sowing. Thinning was done after complete emergence and ten plants per pot were maintained. The recommended dose of metsulfuron-methyl (5 g/ ha) was applied at 3-4 leaf stage of plants using 375 liters of spray volume. The spray was done with knapsack sprayer fitted with flat fan nozzle. Control pots were maintained as untreated or unsprayed. Dry shoot biomass was recorded from untreated control (DMC) and treated pots (DMT) at 30 days after treatment. Growth reduction was calculated as:

$$\text{Growth reduction (\%)} = \frac{\text{DMC} - \text{DMT}}{\text{DMC}} \times 100$$

Based on the growth reduction, locations of the resistant biotypes were plotted on the map of Haryana and Punjab jointly according to their geographic coordinates (latitude and longitude), which were noted down at the time of seed collection with the help of GPS land meter. The location points were plotted with the help of ArcGIS software.

RESULTS AND DISCUSSION

The results of pot study done in winter 2018-19 revealed that 34 out of 56 biotypes of *R. dentatus* collected from Haryana were found resistant to metsulfuron and the resistance pattern was observed almost similar in every district (**Figure 1**). Results revealed that biotype HR 16 which collected from Panipat district of Haryana recorded minimum growth reduction followed by biotype HR 26 which was also collected from Panipat district. This indicated that resistance was more dominant in the Panipat region. Similar findings were also reported by Chhokar *et al.* 2013, Singh (2016), where they reported the resistance in *R. dentatus* to metsulfuron-

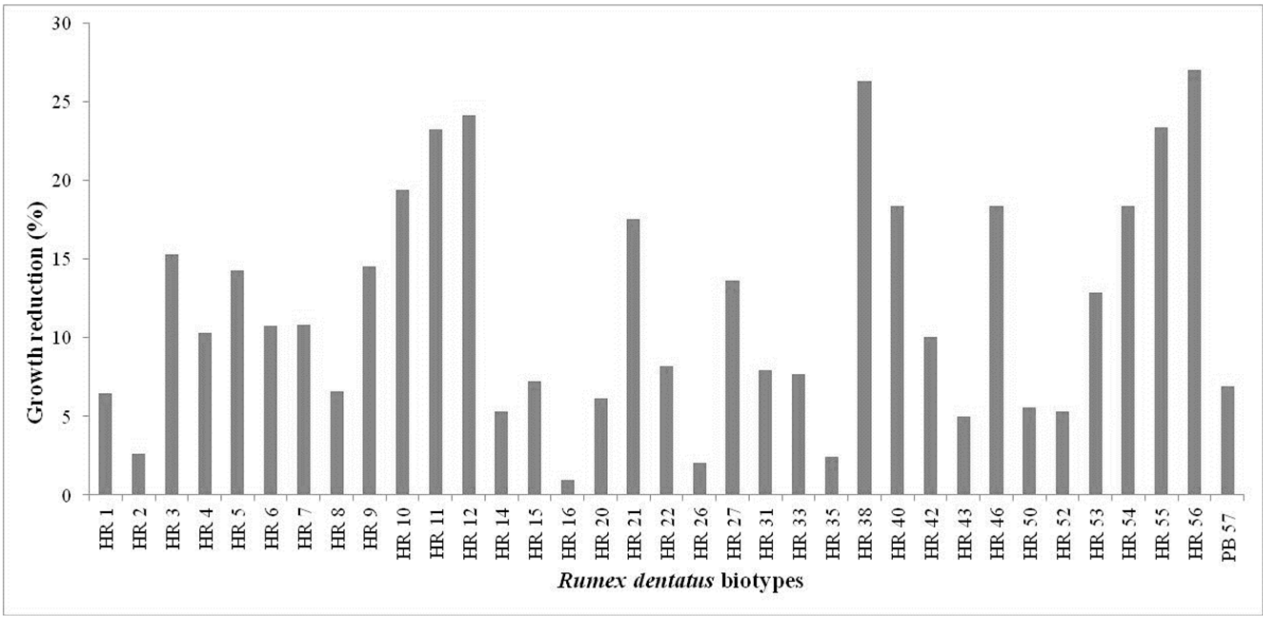

Figure 1. Growth reduction of resistant *R. dentatus* biotypes with Metsulfuron-methyl (5 g/ha) during 2018-19

methyl at farmer's field in Kaithal and Panipat districts of Haryana. In Punjab, only one biotype of *R. dentatus* collected from Barnala district showed resistance to metsulfuron. However, it is important to note that about 68 and 17% of the screened biotypes collected from Haryana and Punjab, respectively was defying action of metsulfuron-methyl and rest were susceptible. *R. dentatus* biotypes collected from Haryana namely HR 13 (Kakkarmajra, Ambala), HR 17 (Sharifgarh, Kurukshetra), HR 18 (Sirsala, Kurukshetra), HR 19 (Nissing, Karnal), HR 23 (Ragsana, Karnal), HR 24 (Habri, Kaithal), HR 25 (Hajwana, Kaithal), HR 28 (Mundwal, Kaithal), HR 30 (Rajankheda, Jind), HR 32 (Safidon, Jind), HR 34 (Kshindu, Panipat), HR 37 (Golimajra, Karnal), HR 39 (Manpura, Karnal), HR 44 (Potli, Yamunanagar), HR 48 (Badshami, Yamunanagar), HR 49 (Sonti, Kurukshetra), HR 51 (Jirbri, Kurukshetra) were found susceptible to the X dose (5 g/ha) of metsulfuron-methyl (**Table 1**). While, in Punjab biotypes collected from the Ludhiana, Sangrur and Jalandhar were found susceptible at X dose. During survey, conversation with farmers in Haryana revealed that putative resistant biotypes were mainly confined to fields where continuous rice-wheat system is being followed along with traditional yearly use of metsulfuron-methyl for controlling broad-leaved weeds in wheat. Moreover, farmers are using sub-lethal dose of metsulfuron (4 g/ha) in Haryana for spray. These factors could partially but enough to explain the evolution of herbicide resistance in *R. dentatus*. However, other factors such as poor spray techniques and delayed application of herbicide would have acted synchronically with above mentioned factors for this defying herbicidal action in Punjab.

The growth of resistant biotypes collected during second year was either unaffected or reduced slightly with spray of metsulfuron-methyl. Growth reduction was less (<30% growth reduction) in the resistant biotypes after the application of herbicide (**Figure 2**). Due to application of metsulfuron-methyl, less than 65% growth reduction was observed in nearly 70% of the screened biotypes of Haryana and 73% of screened biotypes of Punjab. More number of putative resistance biotypes was screened for the resistance from Punjab during the second year that subsequently resulted in more number of confirmed resistance biotypes as compared to first year. Further, the differential growth reduction of the biotypes were observed as some of the biotypes showed moderate resistance while others showed high resistance. This data showed the variability in resistance index of biotypes from different regions of Haryana and Punjab. The biotypes were classified into different groups of resistant (R) having <30%, moderately resistant (MR) having 30-65% growth reduction and susceptible (S) with >65% growth reduction (**Table 1**). A similar classification was adopted by Chhokar and Sharma (2008), Dhawan *et al.* (2010).

The map derived with the help of ArcGIS software clearly indicated that the resistant biotypes were mainly confined to Panipat, Kaithal, Kurukshetra and Karnal districts of Haryana and Fatehgarh Sahib, Patiala and Barnala districts of Punjab (**Figure 3**). Due to continuous application of metsulfuron herbicide for the control of broad-leaf weeds in wheat, *R. dentatus* showed resistance against this herbicide in many regions of Haryana as well as in Punjab state. Earlier, poor control of *R.*

dentatus was reported with metsulfuron-methyl and also with pre-mix application of sulfosulfuron + metsulfuron and mesosulfuron + iodosulfuron in Haryana (Chhokar *et al.* 2018). However, pre-mix application of metsulfuron + carfentrazone provided effective control of resistant *R. dentatus* than application of carfentrazone alone (Singh 2016). Yadav *et al.* (2017) also found that metsulfuron was not effective for controlling *R. dentatus* biotypes from Haryana (Panipat) even at 4 times of recommended dose (16 g/ha) and provided only 17% control at recommended dose (4 g/ha). However, 2,4-D (600 g/ha) and carfentrazone (20 g/ha) provided 98% and 87% control, respectively. But Chhokar *et al.* (2015) reported the comparatively poor control of *R. dentatus* in wheat with all the 2,4-D formulations. The order of effectiveness of three formulations was 2,4-D amine salt followed by 2,4-D ester and 2,4-D sodium salt. Application of carfentrazone, metsulfuron + carfentrazone and halauxifen-methyl + florasulam was found effective for controlling the resistant *R. dentatus.* Singh *et al.* (2017) also reported that herbicide resistance had evolved in *R. dentatus* to metsulfuron-methyl but found effective control with pre-mix application of metsulfuron + carfentrazone. The resistance development in *R. dentatus* is likely to significantly impact the wheat productivity of this food bowl region of India as few herbicide options are available with farmers. Further, zero tillage area is likely to be increased in near future that subsequently makes more favorable ecological conditions for *R. dentatus.* As reports have shown that with the shift in tillage from conventional tillage to zero tillage, the propensity of *R. dentatus* infestation has increased significantly (Chhokar *et al.* 2007). Earlier studies indicated the sustainability issues in this region in the form of accelerated depletion of ground water, declining input factor productivity, imbalance application of fertilizers, adoption of monotonous cropping system (rice-wheat), crop residue burning along with accelerated evolution of herbicide resistance in wheat associated weeds (Humphreys *et al.* 2010, Chauhan *et al.* 2012, Chhokar *et al.* 2018, Chaudhary *et al.* 2019). There is a need to take the lesson from the accelerated development of cross and multiple resistance in *P. minor* within a short period of time from North-Western Indo-Gangetic plains to tackle the proliferation in *R. dentatus*.

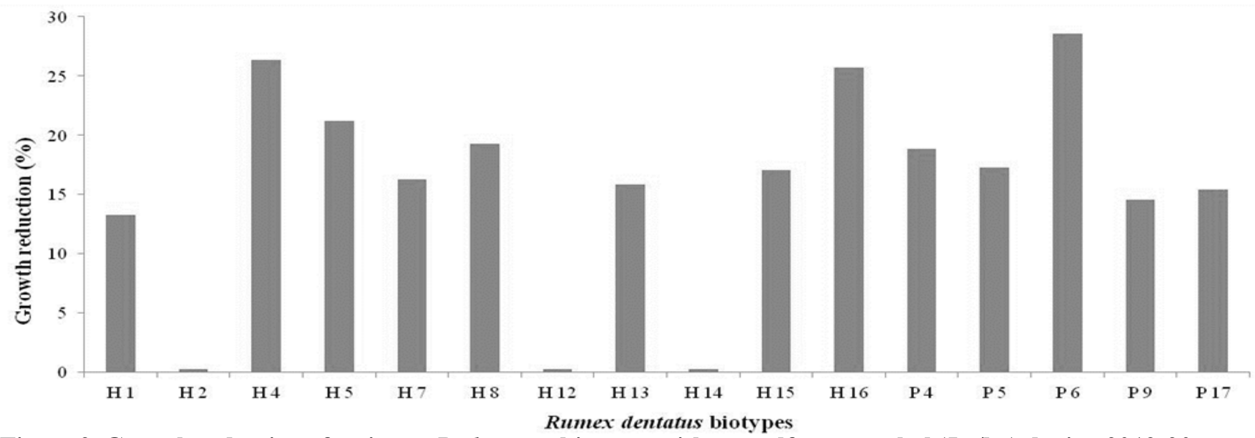

Figure 2. Growth reduction of resistant *R. dentatus* biotypes with metsulfuron-methyl (5 g/ha) during 2019-20

Table 1. Classification of biotypes according to their growth reduction under recommended dose of metsulfuron-methyl (5 g/ha)

Category	Haryana biotypes	Punjab biotypes
Winter *(Rabi)* 2018-19		
Resistant (R)	HR 1, HR 2, HR 3, HR 4, HR 5, HR 6, HR 7, HR 8, HR 9, HR 10, HR 11, HR 12, HR 14, HR 15, HR 16, HR 20, HR 21, HR 22, HR 26, HR 27, HR 31, HR 33, HR 35, HR 38, HR 40, HR 42, HR 43, HR 46, HR 50, HR 52, HR 53, HR 54, HR 55, HR 56,	PB 57
Moderately resistant (MR)	HR 29, HR 36, HR 41, HR 45, HR 47	-
Susceptible (S)	HR 13, HR 17, HR 18, HR 19, HR 23, HR 24, HR 25, HR 28, HR 30, HR 32, HR 34, HR 37, HR 39, HR 44, HR 48, HR 49, HR 51	PB 58, PB 59, PB 60, PB 61, PB 62
Winter *(Rabi)* 2019-20		
Resistant (R)	H 1, H 2, H 4, H 5, H 7, H 8, H 12, H 13, H 14, H 15, H 16	P 4, P 5, P 6, P 9, P 17
Moderately resistant (MR)	H 3, H 6, H 10, H 11, H 17, H 18, H 19, H 20, H 21, H 22, H 23, H 24	P 1, P 2, P 3, P 7, P 8, P 11, P 12, P 13, P 15
Susceptible (S)	H 9, H 25, H 26, H 27, H 28, H 29, H 30, H 31, H 32, H 33	P 10, P 14, P 16, P 18, P 19

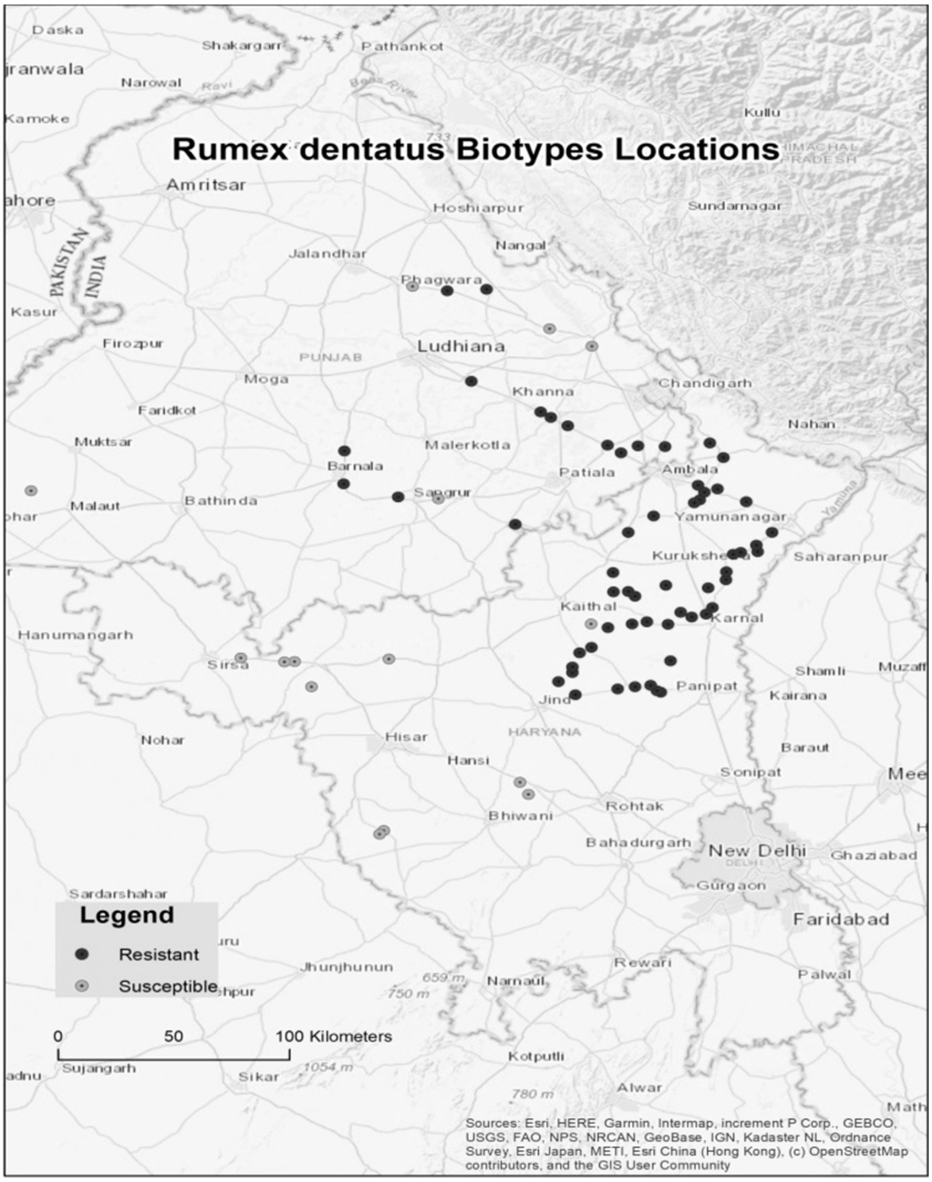

Figure 3. Map showing spread of resistance in *R. dentatus* biotypes collected from Haryana and Punjab

Based on two year studies, this is the first report of confirmation of resistance in *R. dentatus* not only in regions of Panipat but also in other areas such as Kaithal, Kurukshetra and Karnal districts of Haryana implying its wider infestation in the state which was lacking in previous studies. Further, this study also, testifies the infestation of metsulfuron-methyl resistant *R. dentatus* biotypes in Punjab for the first time. The use of metsulfuron-methyl is not economical for the control of *R. dentatus,* where resistance has been confirmed and likely to exacerbate the problem of resistance further. To control the resistant weeds, integrated weed management programs with herbicide of alternate mode of action should be recommended. This resistance is mainly confined in the rice-wheat cropping system with continuous use of same herbicide for broad-laved weed control in wheat. The herbicide resistance in *R. dentatus* after *P. minor* in India is an alarming signal for sustainable wheat production. There is a need to characterize this resistance to decipher the mechanism involved, which helps in devising the new strategies for its management. The concerted efforts are required to understand the biology and ecology of *R. dentatus*, for developing suitable diversified approach to prevent the infestation and its seed production along with large scale adoption of preventing methods such as weed-free fields, use of certified weed free seeds, routine scouting, clean farm equipments free from weed seeds, restricted field-to-field and within-field movement of weed seeds and harvesting of weed seeds should be followed to halt the infestation of *R. dentatus* in wheat. Further, field demonstrations should be conducted for creating awareness among farmers to improve the herbicides efficacy focusing especially about application of recommended dose of herbicides, with right spray nozzle, at right time with rotation of herbicides on yearly basis.

REFERENCES

Anonymous. 2018. *Area, Production and Productivity of Wheat in India*. www.indiaagristat.com.

Chaudhary A, Chhokar RS, Yadav DB, Sindhu VK, Ram H, Rawal S, Khedwal RS, Sharma RK and Gill SC. 2019. In-situ paddy straw management practices for higher resource use efficiency and crop productivity in Indo-Gangetic Plains (IGP) of India. *Journal of Cereal Research* **11**: 172–198.

Chauhan BS, G Mahajan, V Sardana, J Timsina and ML Jat. 2012. Productivity and sustainability of the rice-wheat cropping system in the Indo-Gangetic Plains of the Indian subcontinent: problems, opportunities, and strategies. *Advances in Agronomy* **117**: 315–369.

Chhokar RS and Sharma RK. 2008. Multiple herbicide resistance in littleseed canarygrass (*Phalaris minor*): a threat to wheat production in India. *Weed Biology and Management* **8**: 112–123.

Chhokar RS, Choudhary A and Sharma RK. 2018. Herbicide resistant weeds in India and their management, pp 288-308. In: *Fifty Years of Weed Science Research in India*. (Eds. Sushilkumar and Mishra JS), Indian Society of Weed Science, Jabalpur, India.

Chhokar RS, Sharma RK, and Sharma I. 2012. Weed management strategies in wheat-A review. *Journal of Wheat Research* **4**: 1–21.

Chhokar RS, Sharma RK, Garg R and Sharma I. 2013. Metsulfuron resistance in *Rumex dentatus*. *Wheat Barley* Newsletter **7:** 11.

Chhokar RS, Sharma RK, Gill SC and Meena RP. 2015. Herbicides for broad-leaved weeds management in wheat. *Indian Journal of Weed Science* **47**: 353–361.

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 system. *Crop Protection* **26**: 1689–1696.

Dhawan RS, Bhasker P, Chawla S, Punia SS, Singh S, Angrish R. 2010. Impact of aryloxyphenoxypropionate herbicides on *Phalaris minor* in Haryana. *Indian Journal of Weed Science* **42**: 136–143.

Humphrey E, Kukal SS, Christen EW, Hira GS and Sharma RK. 2010. Halting the groundwater decline in north-west India which crop technologies will be winners? *Advances in Agronomy* **109:** 155–17.

Malik RK, Singh S. 1995. Littleseed canarygrass (*Phalaris minor*) resistance to isoproturon in India. *Weed Technology* **9**: 419–425.

Powles SB and Yu Q. 2010. Evolution in action: plants resistant to herbicides. *Annual Review of Plant Biology* **61**: 317-47.

Rao AN, Wani SP, Ladha JK. 2014. Weed management research in India - an analysis of the past and outlook for future. **18:**1–26. In: *DWR Souvenir* (1989-2014), Directorate of Weed Research, Jabalpur, India.

Singh S, Dhillon A, Gowda P, Irfan M and Kumar P. 2017. Strategies to manage multiple resistant wheat weeds in India to herbicides of several sites of action. p.169. In: *Proceedings of 26th Asian- Pacific Weed Science Society Conference on "Weed science for people, agriculture and nature"*, Kyoto, Japan.

Singh S. 2016. Herbicide resistance in *Rumex dentatus* L. (toothed dock) confirmed. *IWSS Newsletter* April 2016. pp.13–17.

Singh V, Singh H and Raghubanshi AS. 2013. Competitive interactions of wheat with *Phalaris minor* or *Rumex dentatus*: A replacement series study. *International Journal of Pest Management* **59**: 245–258.

Singh V. 2012. *Ecological Analysis of Plant Functional Traits in Agroecosystem* Ph.D. dissertation, Banaras Hindu University, Varanasi, India.

Waheed Z, Usman K and Ali I. 2017. Response of wheat to varying densities of *Rumex dentatus* under irrigated condition of Dera Ismail Khan, Pakistan. *Sarhad Journal of Agriculture* **33**: 1–7.

Whitcomb CE. 1999. An introduction to ALS-inhibiting herbicides. *Toxicology and Industrial Health* **15**: 232–240.

Yadav DB, Punia SS, Singh N and Garg R. 2017. Herbicide resistance in toothed dock population from Haryana.p.63. In: *Proceedings of Biennial Conference on "Doubling Farmers' Income by 2022: The Role of Weed Science"*, 1-3 March, 2017, Udaipur. Indian Society of Weed Science, Jabalpur, India.

Indian Journal of Weed Science **52**(3): 265–269, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Evaluation of multiple herbicide resistance in littleseed canarygrass (*Phalaris minor*) populations from Haryana in India

Maninder Kaur*, Satbir Singh Punia, Jagdev Singh and Samunder Singh

Department of Agronomy, CCS Haryana Agricultural University, Hisar 125004, India

**Forage and Millet Section, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana 141004*

**Email: maninder.sindhu@yahoo.com*

Article information

DOI: 10.5958/0974-8164.2020.00051.9

Type of article: Research article

Received : 7 April 2020
Revised : 8 August 2020
Accepted : 14 August 2020

Key words

ACCase inhibitors

ALS inhibitors

Multiple herbicide resistance

Phalaris minor

ABSTRACT

Phalaris minor is seriously affecting wheat productivity and profitability in Haryana. The menace of *P. minor* has worsened after it evolved resistance to herbicides. For rational recommendation and implementation of management strategies, it is imperative to assess and quantify the level of resistance in *P. minor* populations. In dose-response assay, it was found that *P. minor* populations 'Naggal' and 'Kalvehri' exhibited multiple resistance to herbicides from different chemical families. 'Naggal' was 13-, 18-, 26- and 22-fold resistant to clodinafop, pinoxaden, sulfosulfuron and mesosulfuron + iodosulfuron, respectively and 'Kalvehri' was 15-, 29- and 16-fold resistant to pinoxaden, sulfosulfuron and mesosulfuron + iodosulfuron, respectively. All tested populations were resistant to ACCase inhibitors with more number of populations being highly resistant to clodinafop than pinoxaden. However, majority of the populations were susceptible to ALS inhibitors particularly mesosulfuron + iodosulfuron. The evolution of multiple herbicide resistance in *P. minor* is a big challenge for scientists and farmers alike.

INTRODUCTION

In India, wheat (*Triticum aestivum* L.) is the second most important food grain crop after rice, grown in 30 million ha (14% of global area) with 99.7 million tonnes of production (Anonymous 2018). The states of Punjab and Haryana in the North-Western plains are major producers of wheat. Among the many factors, the two most important constraints for declining the total factor productivity of rice-wheat cropping system in these states are *Phalaris minor* (Retz.) and deterioration in soil productivity (Vincent and Quirke 2002). *P. minor* is a highly competitive weed thriving on highly fertile and moist soils (Singh 2007). Grain yield losses of wheat caused by *P. minor* vary between 25 to 50% (Chhokar and Sharma 2008) and may cause the complete failure of wheat in case of severe infestation (2000-3000 plants/m^2). However, greater dependence on herbicides has led to the rapid evolution of herbicide resistance in weeds of wheat. Globally, maximum number of cases of herbicide-resistant weeds *i.e.* 75 has been reported to infest wheat among all crops (Heap 2017). *P. minor* is one such notorious weed, which has evolved different mechanisms to defy many wheat herbicides. The evolution of herbicide resistance in *P. minor* began for the first time against isoproturon during 1992-93 in India which was also the first and the most serious case of herbicide resistance in *P. minor* in the world (Malik and Singh 1995).

To control the spread of isoproturon resistant *P. minor*, a number of new herbicides recommendations with different mode of action were introduced (Punia *et al.* 2008). However, the dreadful *P. minor* evolved biological defense against these new herbicides too. Some *P. minor* populations from Punjab and Haryana were found to be resistant to the newly recommended herbicides eg. pinoxaden without any prior history of exposure, indicating evolution of cross-resistance (Dhawan *et al.* 2010). Similarly, few populations have been found to have very high GR_{50} value for a herbicide, mesosulfuron + iodosulfuron (Dhawan *et al.* 2012). Vincent and Quirke (2002) based on their model suggested that the areas with resistant biotypes of *P. minor* in wheat in North Western India would be approximately 1.2 million ha with more in Haryana state (+70%) than in Punjab state (+20%). Thus, the rapid evolution of multiple resistant *P. minor* populations and their extensive spread is not only threatening the wheat yield of resistance-affected farmers but also nation's food security. Hence, the characterization of resistance in *P. minor* populations with regard to profile (single, cross, multiple) and magnitude (fold level) has become vital for rationale recommendation and implementation of effective management strategies. Keeping this in view, the present study was conducted to confirm multiple herbicide resistance in *P. minor* populations from Haryana and to quantify the resistance profiles of *P. minor* populations for significant implications in designing future resistance management strategies.

MATERIALS AND METHODS

Plant materials

In April 2013, seeds of fourteen populations of *P. minor* were collected from locations where farmers reported poor control of the weed with recommended alternate herbicides (clodinafop, sulfosulfuron, fenoxaprop) after the failure of earlier recommended isoproturon to control these *P. minor* populations. Seeds from Hisar-CCSHAU Research Farm were also collected from plots, which had never been sprayed with the herbicides. This population has earlier been confirmed as sensitive and therefore used as standard susceptible check for comparison. The information with respect to history of herbicide use followed in different locations from where the *P. minor* populations were collected is mentioned (**Table 1**).

Table 1. Origin and herbicide use history of different *P. minor* populations collected for confirmation of multiple herbicide resistance

Location	Population	Herbicide use history
Saanch, Kaithal	Saanch	Clodinafop and sulfosulfuron
Pundri, Kaithal	Pundri	Clodinafop and sulfosulfuron
Geong, Kaithal	Geong	Clodinafop and fenoxaprop
Sola, Kurukshetra	Sola	Clodinafop
Rampur, Kurukshetra	Rampur	Clodinafop
Morthali, Kurukshetra	Morthali	Clodinafop
Naggal, Ambala	Naggal	Clodinafop and fenoxaprop
Naranga Majra, Ambala	Naranga Majra	Clodinafop and pinoxaden
Kalvehri, Karnal	Kalvehri	Clodinafop
Takhana, Karnal	Takhana	Clodinafop, fenoxaprop and sulfosulfuron
Kachwa, Karnal	Kachwa	Clodinafop
Danauda, Jind	Danauda	Clodinafop
Rania, Sirsa	Rania	Clodinafop and sulfosulfuron
Silani, Jhajjar	Silani	Clodinafop and sulfosulfuron
Hisar, CCSHAU Farm	Hisar	No herbicide

Dose-response studies

Greenhouse experiments for dose-response bioassays were conducted during the winter seasons of 2014-15 and 2015-16 to determine the levels of resistance in selected *P. minor* populations to recommended alternate herbicides *i.e.,* clodinafop, pinoxaden, sulfosulfuron and mesosulfuron + iodosulfuron at registration doses in screen house of Department of Agronomy, CCSHAU, Hisar. Dose ranges were generated according to registered field rates for post-emergence application of these herbicides. These doses correspond to 0.5, 1.0 and 2.0 times the recommended field rate of the products in India. Recommended dose for different herbicides is: clodinafop 60 g, pinoxaden 50 g, sulfosulfuron 25 g and mesosulfuron + iodosulfuron 14.4 g/ha. Dose-response experiments for each herbicide were conducted using a completely randomized design with four replications per treatment. One untreated control was also kept for each population for comparison. Seeds of different *P. minor* populations were sown by November end during both the years in pots (93 diameter) filled with sandy loam soil. Soil for filling the pots was taken from the field in Agronomy research area, which was not sprayed with herbicides during the last two years and was not infested with *P. minor*. The soil was air-dried, crushed, well ground to pass through a sieve of 2 mm pore size before filling in the pots along with vermin-compost in the ratio of 4:1. The pots were watered before sowing in order to maintain optimum soil moisture and to exhaust the soil weed seedbank. Seeds of *P. minor* populations (50 each) were sown in four replicates at a depth of 0.5-1.0 cm. Two weeks after the emergence of *P. minor* plants, thinning was done and 10 plants per pot were maintained for the spray of herbicide. The plants were sprayed at 3-4 leaf stage with clodinafop 30, 60, and 120 g/ha; sulfosulfuron 12.5, 25 and 50 g/ha; mesosulfuron+ iodosulfuron 7.2, 14.4 and 28.8 g/ha and pinoxaden 25, 50 and 100 g/ha for assessment of the herbicidal efficacy. Herbicides were sprayed with a knapsack sprayer fitted with flat fan nozzle delivering 375 l/ha spray volume at 40 psi pressure. The plants that remained unsprayed with herbicide served as control. Dry weight data of *P. minor* populations at 30 DAT were regressed over herbicide treatments using the three-parameter log-logistic model (Seefeldt *et al.* 1995).

$$y = d/1 + \exp [b - (\log (x) - \log (e))]$$

Where, y is the response variable (dry weight g/plant), d is the upper limit, b is the slope of the line, e is the dose resulting in a 50% dry weight control (known as GR_{50}) and x is the herbicide dose. Analysis of dose–response curves were performed separately for each *P. minor* population and GR_{50} values were determined using the *drc* package (drc 1.2, Christian

Ritz and Jens Strebig, R2.5, Kurt Hornik online) in software R (R statistical software, R Foundation for Statistical Computing, Vienna, Austria; http:// www.R-project.org) (Ritz and Streibig 2005). The level of resistance (resistance index) for different populations was determined by dividing the GR_{50} value of the populations with the GR_{50} value of the susceptible population. The values >2 were considered to be resistant.

RESULTS AND DISCUSSION

The GR_{50} values (dose required to cause 50% reduction in dry weight) for the *P. minor* populations for different herbicides are presented in **Table 2**. Majority of the populations tested were not sensitive to the application of clodinafop. The GR_{50} values for clodinafop for all the populations was more than the recommended dose (60 g/ha) except for Kalvehri, Rania, Silani and Hisar which recorded GR_{50} values less than the recommended dose. The highest GR_{50} value (≥4 times the recommended dose) for clodinafop was observed for Kachwa (245-298 g/ha) followed by Morthali (226-267 g/ha), Naggal (215-244 g/ha), Rampur (177-228 g/ha) and Geong (187-205 g/ha) which had GR_{50} values ≥3 times the recommended dose of clodinafop. *P. minor* populations Pundri, Sola and Danauda also recorded higher GR_{50} values. However, Saanch, Naranga Majra, Takhana showed moderate resistance to clodinafop and had GR_{50} values in the range of 60-85 g/ha, which were slightly above the recommended dose of clodinafop.

The GR_{50} values for pinoxaden for different *P. minor* populations varied in the range of 10-209 g/ha. The lowest GR_{50} values were recorded for Silani (12 g/ha) and Hisar (10-11 g/ha) while the highest GR_{50} values (2.9 to 4.2 times the recommended dose) for pinoxaden were recorded for Naggal (161-209 g/ha) followed by Morthali (160-189 g/ha) and Kalvehri (143-157 g/ha). Saanch, Pundri also recorded GR_{50} values higher than the recommended dose. Geong, Sola, Rampur, Naranga Majra, Takhana, Kachwa, Danauda and Rania had lower GR_{50} values varying from 26-62 g/ha. The *P. minor* populations showed a differential response to the application of sulfosulfuron and mesosulfuron + iodosulfuron. The GR_{50} values for sulfosulfuron for majority of the *P. minor* populations remained below the recommended dose (25 g/ha) except for Naggal and Kalvehri which showed much higher GR_{50} values of 86-92 and 84-113 g/ha, respectively *i.e.* 3.4 to 4.5 times the recommended dose for sulfosulfuron whereas for Takhana, Kachwa and Danauda, GR_{50} values (17-26 g/ha) were around the recommended dose of sulfosulfuron.

Likewise, for mesosulfuron + iodosulfuron, the GR_{50} values for all the populations were in the range of 3-8 g/ha, much below the recommended dose (14.4 g/ha) except for Naggal and Kalvehri which showed GR_{50} values 2.5 to 4.9 times the recommended dose.

The resistance index for population Hisar which was used as the standard susceptible *P. minor* population was 1.0 for all the herbicides (**Table 3**). The resistance index for clodinafop was between 2.4 and 5.0 for Kalvehri, Takhana, Saanch and Naranga Majra, while for Pundri, Geong, Sola, Rampur, Morthali, Naggal, Kachwa and Danauda the resistance indices ranged from 7.9-16.2. *P. minor* populations Rania and Silani had resistance indices in the range of 0.8-1.5. For pinoxaden, lower resistance indices in the range of 2.6-5.7 were observed for Geong, Sola, Rampur, Naranga Majra, Takhana, Kachwa, Danauda and Rania whereas Saanch, Pundri, Morthali, Naggal and Kalvehri showed higher

Table 2. GR_{50} (g/ha) values of *P. minor* populations for different herbicides based on per cent reduction in dry weight 30 DAT

Population	Clodinafop		Pinoxaden		Sulfosulfuron		Mesosulfuron + iodosulfuron	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Saanch	60	71	76	93	6	13	6	4
Pundri	119	214	83	116	6	9	3	4
Geong	187	205	37	45	7	8	8	7
Sola	138	197	42	28	7	7	3	5
Rampur	177	228	30	35	5	13	2	5
Morthali	226	267	160	189	3	10	3	5
Naggal	215	244	161	209	92	86	46	70
NarangaMajra	76	68	37	53	7	15	5	8
Kalvehri	37	54	143	157	84	113	36	47
Takhana	67	85	38	42	22	26	5	7
Kachwa	245	298	36	62	17	23	5	4
Danauda	134	206	26	27	20	20	3	5
Rania	22	15	26	32	5	10	5	3
Silani	22	22	12	12	5	6	3	3
Hisar	15	20	10	11	3	4	3	3

resistance indices in the range of 8.0-19.5. Silani had resistance index value fairly close to that of Hisar. For sulfosulfuron, the highest resistance index values were observed for Naggal (27.9-29.7) and Kalvehri (30.5-22.7). Populations Takhana, Kachwa and Danauda had resistance indices of 5.2-7.2 while remaining populations showed much lower resistance indices. Resistance indices for mesosulfuron + iodosulfuron was d"3 for all the populations except for Naggal and Kalvehri which showed highest resistance indices of 18.5-25.9 and 14.3-17.4, respectively.

The GR_{50} values of *P. minor* populations for different herbicides showed intriguing trends (**Table 2**) and variation in GR_{50} values over the two years could be due to variation in dry weight data over two seasons. The GR_{50} values of all populations were greater than the susceptible population (Hisar) with clodinafop. However, Rania and Silani with clodinafop had GR_{50} values similar to susceptible population and with pinoxaden, Rania had greater GR_{50} value than both Silani and Hisar populations. The dose of sulfosulfuron required for 50% growth reduction of Naggal, Kalvehri, Takhana, Kachwa and Danauda was much higher than that of the susceptible Hisar population while all other populations had similar dose requirement for reducing their growth by 50% as that for Hisar. Mesosulfuron + iodosulfuron caused 48-90% mortality of the test populations and the same was reflected in the GR_{50} values except for Naggal and Kalvehri, which required 12 to 23.3 times higher dose of mesosulfuron + iodosulfuron compared to susceptible Hisar population for the same level of effect. Based on the GR_{50} and resistance index, *P. minor* populations were found to have variable levels of resistance and resistance pattern to applied herbicides. From the herbicide resistance profiles of *P. minor* populations, it was observed that majority of the tested *P. minor* populations were resistant to acetyl-CoA carboxylase (ACCase) inhibitors (clodinafop and pinoxaden) whereas majority of the populations were found to be susceptible or having low level of resistance to acetolactate synthase (ALS) inhibitors (sulfosulfuron and mesosulfuron + iodosulfuron). The level of resistance to clodinafop was found to be high (10.4- to 16.2-fold) for Geong, Rampur, Morthali, Naggal and Kachwa; medium (7.9- to 10.8-fold) for Pundri, Sola and Danauda; low (2.4- to 5.0-fold) for Saanch, Naranga Majra, Kalvehri and Takhana. *P. minor* populations Morthali, Naggal and Kalvehri displayed high level of resistance (14.6- to 19.5- fold), Saanch and Pundri had medium level of resistance (8.0- to 10.8-fold) and Geong, Naranga Majra, Takhana, Kachwa and Danauda were low in resistance (2.6- to 5.7-fold) against pinoxaden. When treated with sulfosulfuron, Naggal and Kalvehri revealed very high level of resistance (22.7- to 30.5-fold); Takhana, Kachwa and Danauda indicated medium level of resistance (5.2- to 7.2- fold) and whereas rest of the populations showed low level of resistance. Very high level of resistance against mesosulfuron + iodosulfuron was shown by Naggal and Kalvehri populations (14.3- to 25.9- fold) whereas other populations were low in resistance or susceptible.

P. minor populations Naggal and Kalvehri were found to be highly resistant to both group of herbicides. Their high resistance indices indicated towards target-site resistance. Kaundun (2007) previously reported the first case of target-site resistance in one biotype of *P. minor* from India. The alteration of target enzyme in resistant weed populations confers a very high level of resistance to ACCase and ALS inhibitors similar to observed in the present investigation. Gherekhloo *et al.* (2008)

Table 3. Resistance index of *P. minor* populations for different herbicides

Population	Clodinafop		Pinoxaden		Sulfosulfuron		Mesosulfuron + iodosulfuron	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Saanch	4.0	3.6	8.0	8.7	2.0	3.4	2.4	1.4
Pundri	7.9	10.8	8.7	10.8	1.9	2.3	1.1	1.5
Geong	12.4	10.4	3.9	4.2	2.3	2.1	3.2	2.6
Sola	9.1	10.0	4.4	2.6	2.4	1.8	1.3	1.7
Rampur	11.7	11.6	3.2	3.3	1.7	3.3	0.7	1.9
Morthali	14.9	13.6	16.8	17.6	0.9	2.5	1.3	2.0
Naggal	14.3	12.4	17.0	19.5	30.5	22.7	18.5	25.9
NarangaMajra	5.0	3.4	3.9	4.9	2.4	3.9	1.8	2.9
Kalvehri	2.4	2.7	15.1	14.6	27.9	29.7	14.3	17.4
Takhana	4.4	4.3	4.0	4.0	7.2	6.9	2.1	2.6
Kachwa	16.2	15.1	3.7	5.7	5.7	6.0	2.0	1.6
Danauda	8.9	10.5	2.8	2.6	6.6	5.2	1.3	1.8
Rania	1.5	0.8	2.8	3.0	1.7	2.8	2.0	1.3
Silani	1.5	1.1	1.2	1.1	1.8	1.7	1.4	1.2
Hisar	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Resistance index: GR_{50} of resistant population/GR_{50} of susceptible population (Hisar, CCSHAU Farm) reported very high resistance in three *P. minor* populations to fenoxaprop due to an altered ACCase enzyme. Likewise, very high level of resistance in *Lolium multiforum* to diclofop and in *Setaria faberi* and *Digitania sanguinalis* to sethoxydim has been documented due to an altered ACCase enzyme (Volenberg and Stoltengerg 2002). Greater than 10-fold resistance conferred by modification of target site has been documented in several weed species that are resistant to herbicides inhibiting ALS enzyme (Eberlein 1999). Resistance to isoproturon in these populations has earlier been documented due to non-target site mechanism *i.e.* enhanced metabolism/ detoxification of isoproturon (Singh 1998). The prevalence of multiple resistance in *P. minor* populations has been reported earlier by Singh (2015) and Chhokar and Sharma (2008). These results were in conformity with the earlier findings of Dhawan *et al.* (2009) and Dhawan *et al.* (2010) who reported high or medium level of resistance in most of the populations tested against clodinafop. The occurrence of resistance (high to medium) against pinoxaden in some *P. minor* populations showing resistance to clodinafop indicated towards cross-resistance to this herbicide. While, sulfosulfuron and mesosulfuron + iodosulfuron remained effective on the majority of the tested *P. minor* populations. Similarly, Travlos (2012) found that about half of the diclofop resistant *P. minor* populations were at least equally or more sensitive to mesosulfuron + iodosulfuron than the sensitive population used as standard for comparison. However, contrasting results were reported by Dhawan *et al.* (2012). They found that none of the *P. minor* population was susceptible to sulfosulfuron and only one population was susceptible to mesosulfuron + iodosulfuron.

It was concluded that *P. minor* populations in Naggal, Ambala, Kalvehri and Karnal have evolved multiple herbicide resistance. Furthermore, the dominance of *P. minor* populations resistant to ACCase inhibitors chiefly clodinafop in present investigation undoubtedly specifies the extended selection pressure for resistant *P. minor* from the unabated use of clodinafop in farmers' fields.

REFERENCES

Anonymous. 2018. Ministry of Agriculture and Farmers Welfare, Government of India. 2018. Available from: https:// eands.dacnet.nic.in/Advance_ Estimate/4th_Adv_ Estimates2017-18_ Eng.pdf [Accessed: December 25, 2018].

Chhokar RS and Sharma RK. 2008. Multiple herbicide resistance in littleseed canarygrass (*Phalaris minor*) - A threat to wheat production in India. *Weed Biology and Management* **8**: 112–123.

Dhawan RS, Bhaskar P, Chawala S, Punia SS, Singh S and Angrish R. 2010. Impact of aryloxyphenoxypropionate herbicides on *Phalaris minor* in Haryana. *Indian Journal of Weed Science* **42**(3&4): 136–143.

Dhawan RS, Punia SS, Singh S, Yadav D and Malik RK. 2009. Productivity of wheat as affected by continuous use of new low dose herbicides for management of littleseed canarygrass (*P. minor*) in India. *Indian Journal of Agronomy* **54**: 58–62.

Dhawan RS, Singh Neha and Singh S. 2012. Littleseed canary grass resistance to sulfonyl-urea herbicides and its possible management with pendimethalin. *Indian Journal of Weed Science* **44**(4): 218–224.

Eberlein CV, Guttieri MJ, Berger PH, Fellman JK, Mallory-Smith CA, Thill DC, Baerg RJ and Belkmap WR. 1999. Physiological consequences of mutation for ALS-inhibitor resistance. *Weed Science* **47**: 383–392.

Gherekhloo J, Mohassel HR, Mahalati MN, Zand E, Ghanbari A, Osuna MD and De Prado R. 2008. Seed bioassay and ACCase enzyme assay to study the resistance of *Phalaris minor* to aryloxyphenoxypropionate (APP) inhibitors. *Environmental Sciences* **6**(1): 43–52.

Kaundun D. 2007. Occurrence and management of herbicide resistance. In, *Proceedings of the National Symposium on Herbicide Resistance in the Rice-Wheat Cropping Systems*. CCS Haryana Agricultural University, Hisar, India.

Heap I. 2017. International Survey of Herbicide Resistant Weeds. Last updated July 26, 2016. URL www.weedscience.org

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

Punia SS, Yadav DB, Singh S and Dhawan RS. 2008. Evaluation of different herbicides against clodinafop resistant population of *P. minor* in wheat. pp. 322–323. In: *Proceedings of National Symposium on New Paradigm shifts in Agronomic Research*, 19-21 November 2008, GAU, Navsari.

Ritz C and Streibig JC. 2005. Bioassay Analysis using R. *Journal of Statistical Software* **12**: 1–22.

Seefeldt SS, Jensen JE and Fuerst EP. 1995. Log-logistic analysis of herbicide dose-response relationships. *Weed Technology* **9**: 218–227.

Singh S. 1998. *Studies on the Mechanism of Isoproturon Resistance in (Littleseed Canarygrass)*. Ph.D. Thesis, University of Strathclyde, Glasgow, UK.

Singh S. 2007. Role of management practices on control of isoproturon-resistant littleseed canarygrass (*Phalaris minor*) in India. *Weed Technology* **21**: 339–346.

Singh S. 2015. Management of multiple herbicide resistant in *Phalaris minor* in India. *Proceedings, Volume II (oral papers). 25th Asian Pacific Weed Science Society Conference.* Hyderabad, India, 21 pp.

Travlos IS. 2012. Evaluation of herbicide-resistance status on populations of littleseed canarygrass (*P. minor* Retz.) from Southern Greece and suggestions for their effective control. *Journal of Plant Protection Research* **52**: 308–313.

Vincent D and Quirke D. 2002. Controlling *Phalaris minor* in the Indian rice-wheat belt. *ACIAR Impact Assessment Series* **18**: 35.

Volenberg D and Stoltengerg D. 2002. Altered acetyl CoA carboxyloase resistance to clethodim, fluazifop and sethoxydim in *Setaria faberi* and *Digitaria sanguinalis*. *Weed Research* **42**: 342–350.

Indian Journal of Weed Science **52**(3): 270–275, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Physiological response of rice to herbicide application

C. Linu* and T. Girija

College of Horticulture, Vellanikkara, KAU P.O, Thrissur, Kerala 680 656, India

**Email: linu797@gmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00052.0

Type of article: Research note

Received : 13 May 2020
Revised : 8 August 2020
Accepted : 10 August 2020

Key words

Indole acetic acid content

Net photosynthesis

Nitrate reductase enzyme activity

Proline content

Soluble protein content

ABSTRACT

The experiment was conducted at Agricultural Research Station, Mannuthy in the year 2018 with the rice variety '*Jyothi*'. The experiment was laid out in RBD with three replications. Treatments included recommended and double the recommended doses of 2,4-D, metsulfuron-methyl + chlorimuron-ethyl and penoxsualm and two controls (hand weeded and unweeded). Herbicides were sprayed at 20 days after sowing (DAS). Biochemical parameters were estimated at one week after herbicidal application and at the time of flowering. Biochemical parameters such as soluble protein, total amino acid and nitrate reductase enzyme activity showed a decline in herbicide treatments compared to hand weeded control. Proline content and catalase enzyme activity showed an increase with herbicide application while other physiological parameters like Indole acetic acid (IAA) content, chlorophyll content, stomatal conductance and net photosynthesis showed a decline. Double the recommended dose of herbicides affected these parameters more adversely as compared to the recommended dose of herbicides. Even though double the recommended dose of herbicide exhibited higher weed control efficiency, it reduced the yield of rice plant.

Rice is the third most cultivated cereal in the world and it is the staple food for more than half of the world's population. Due to rapid growth of population, the production has to be increased further. To achieve this goal, it is important to reduce crop loss caused by weed competition. Weeds not only reduce production but also reduce the grain quality of rice (Ramanarayana 2014). Different post-emergence herbicides are used to control already emerged weeds which compete with the developing crop. 2,4-D, penoxsulam and ready-mix formulations of metsulfuron-methyl 10% + chlorimuron-ethyl 10% are some popular post-emergence herbicides currently used in Kerala. 2,4-D is the most widely used auxinic herbicide that is used for the control of broadleaved weeds and sedges without affecting monocots. Penoxsulam and metsulfuron-methyl + chlorimuron-ethyl are the herbicides which inhibit the synthesis of essential enzyme acetolactate synthase (ALS). Selectiveness of herbicides to certain weeds accounts for the usage of high dosages of the herbicides by farmers. The present study aimed at understanding the impact of excess usage of herbicides on physiology of rice crop.

The study was conducted in the year 2018 during the *Kharif* season in Agricultural Research Station, Mannuthy, Thrissur. The experiment was laid out in randomized bock design with eight treatments replicated three times. Plot size was 5 x 3 m (15 m^2). The rice variety selected for the study was '*Jyothi*'. The treatments included recommended and double the recommended doses of 2,4-D (0.8 and 1.6 kg/ha), metsulfuron-methyl + chlorimuron-ethyl (0.004 and 0.008 kg/ha) and penoxsulam (0.025 and 0.05 kg/ha) and two hand weeding (HW) at 20 and 60 DAS and without any weeding operation cited as unweeded (UW) in the text. The herbicides were sprayed at 20 DAS. Plant samples were collected one week after herbicide application and at the time of flowering for biochemical analysis.

The content of chlorophyll a, chlorophyll b and total chlorophyll were measured by the method adopted by Hiscox and Israelstam (1979). While the photosynthetic rate and stomatal conductance were calculated by using infrared gas analyzer (Model LI-6400 of ICOR Inc. Licoln, Nebraska, USA). The reading was taken from 8 am to 10 am. Indole acetic acid (IAA) was estimated by the method proposed by Parthasarathy *et al*. (1970) using Garden weber reagent.

Total soluble protein was estimated using the method suggested by Lowry *et al.* (1951). The content of total aminoacid was estimated using ninhydrin method proposed by Mooreand Stein (1948). The activity of catalase enzyme (CAT) was estimated by permanganate titration method of Barber (1980). Proline content was estimated by the method of Bates *et al.* (1973). The content nitrate reductase enzyme in the leaf was estimated by the method given by Hageman and Flesher (1960). The nitrite formed was estimated by the method described by Nicholas *et al.* (1976), by measuring the absorbance at 540 nm using spectrophotometer. Weed control efficiency calculated using the formula suggested by Mani *et al.* (1973). The crop harvested from each replication was threshed, winnowed and weighed separately. The straw and grain weights were recorded separately and expressed in t/ha. The data were subjected to statistical package WASP and SPSS. Multiple comparison among treatment means, where the F test was significant (at 5% level) were done with Duncan's Multiple Range Test.

Estimation of chlorophyll content of the rice plants at one week after herbicide application and at flowering stages revealed that there was significant reduction in chlorophyll a for all the dosages of herbicides as compared to hand weeded control (**Table 1** and **2**). This was also reflected in the total chlorophyll content. However, the chlorophyll b content did not show significant variation in the treatments where recommended dose of herbicides was applied. Application of higher doses of herbicides significantly reduced both chlorophyll a and chlorophyll b content. Earlier, Sahoo *et al.* (1993) reported that the effect of post emergence herbicide on total chlorophyll content was dose dependent, especially during the early stages of crop growth.

At flowering, chlorophyll b content was found to be significantly lower than the hand weeded control in all the treatments. However, the values of chlorophyll a was found to be at par with the hand weeded control in case of treatments where normal dose of the herbicides was applied. This confirmed to the findings of Ralph *et al.* (2000). Application of double the recommended dose of herbicides reduced the chlorophyll content in 2,4-D, metsulfuron-methyl + chlorimuron-ethyl and penoxsulam. This might be due to the fact that herbicides in general inhibit the common enzyme between the pathway of chlorophyll and cytochrome synthesis and cause the formation of an intermediate tetrapyrroline which prevented the formation of chlorophyll pigment (Matringe *et al.* 1989). Among the herbicides tested,

Table 1. Effect of herbicides on chlorophyll content of rice plant at 7 days after herbicide (DAH) application (mg/g of fresh leaf)

Treatment	Chlorophyll		Total chlorophyll
	a	b	
2,4-D (800 g/ha)	3.55^{b}	1.05^{ab}	4.60^{ab}
2,4-D (1600 g/ha)	3.07^{d}	0.814^{cd}	3.88^{e}
Metsulfuron-methyl + chlorimuron-ethyl (4 g/ha)	3.23^{c}	0.951^{abcd}	4.18^{cd}
Metsulfuron-methyl + chlorimuron-ethyl (8 g/ha)	2.39^{f}	0.740^{d}	3.13^{g}
Penoxsulam (25 g/ha)	3.42^{b}	0.970^{abc}	4.39^{bc}
Penoxsulam (50 g/ha)	2.81^{e}	0.799^{cd}	3.60^{f}
Two hand weeding at 20 and 60 DAS	3.72^{a}	1.12^{a}	4.84^{a}
Unweeded	3.15^{cd}	0.873^{bcd}	4.02^{de}
LSD (p=0.05)	0.148	0.215	0.237

Table 2. Effect of herbicides on chlorophyll content of rice plant at flowering (mg/g of fresh leaf)

Treatment	Chlorophyll		Total chlorophyll
	a	b	
2,4-D (800 g/ha)	2.25^{ab}	1.12^{b}	3.38^{b}
2,4-D (1600 g/ha)	1.88^{c}	0.75^{cd}	2.63^{d}
Metsulfuron-methyl + chlorimuron-ethyl (4 g/ha)	2.25^{ab}	1.10^{b}	3.34^{b}
Metsulfuron-methyl + chlorimuron-ethyl (8 g/ha)	1.55^{d}	0.70^{d}	2.25^{e}
Penoxsulam (25 g/ha)	2.21^{ab}	1.06^{b}	3.27^{b}
Penoxsulam (50 g/ha)	1.13^{e}	0.522^{e}	1.65^{f}
Two hand weeding at 20 and 60 DAS	2.33^{a}	1.90^{a}	4.22^{a}
Unweeded	1.99^{bc}	0.903^{c}	2.89^{c}
LSD (p=0.05)	0.287	0.157	0.191

recommended dose of 2,4-D had the least damage on chlorophyll content and the result corroborated well the early report of Ivanov *et al.* (2002) who stated that lower concentration of 2,4-D showed less reduction in chlorophyll content compared to higher concentration.

IAAis a plant growth regulator produced in the shoot tip and moves to the root activating cell division and elongation. It is also a signalling molecule necessary for plant growth and development (Taiz and Zeiger 1991). In the present study, IAA content of the rice plant was significantly reduced by herbicides (**Table 3)** and this did not improve even at the time of flowering. The reduction was higher in the plants where double the recommended dose of the herbicide was applied. Similar results were reported by Ramanarayana (2014) in the case of ALS inhibitors such as metsulfuron-methyl + chlorimuron-ethyl and azimsulfuron. Machackova and Matschke (2002) observed 30% reduction in IAA content after application of 2,4-D and 15% after application of glyphosate in oak trees. Among the herbicides, normal dose of 2,4-D showed least reduction in IAA content at 7 DAH application and flowering (0.250, 0.250).

Table 3. Effect of herbicides on IAA content of rice plant (mg of unoxidized auxin/g fresh weight)

Treatment	7 DAH application	At flowering
2,4-D (800 g/ha)	0.250^{b}	0.250^{b}
2,4-D (1600 g/ha)	0.175^{d}	0.108^{d}
Metsulfuron-methyl + chlorimuron-ethyl (4 g/ha)	0.200^{c}	0.217^{c}
Metsulfuron-methyl + chlorimuron-ethyl (8 g/ha)	0.142^{e}	0.075^{e}
Penoxsulam (25 g/ha)	0.200^{c}	0.200^{c}
Penoxsulam (50 g/ha)	0.150^{e}	0.050^{f}
Two hand weeding at 20 and 60 DAS	0.300^{a}	0.308^{a}
Unweeded	0.200^{c}	0.200^{c}
LSD (p=0.05)	0.009	0.023

The net photosynthetic rate was found to be affected by herbicide application (**Table 4**). As compared to hand weeded control (31.90 and 9.11µ mol CO_2/ m^2/ s, respectively, at 7 DAH application and at flowering) all the herbicides significantly reduced the net photosynthesis. The effect was more pronounced as the dose was increased. Among the herbicides, recommended dose of 2,4-D had the least effect on the photosynthesis of the rice plant and this was consistent with the effect being recorded in case of chlorophyll. Tejada *et al.* (2013) reported that net photosynthesis reduced when the plant was affected with chlorosis, indicating chlorophyll content as an indicator of net photosynthesis. Zhou *et al.* (2007) reported that the application of ALS inhibiting herbicides caused an inhibition of acetolactose synthase enzyme that interrupts synthesis of aminoacids like valine, leucine, isoleucine and this, finally resulted in the decline of photosynthetic rate.

Table 4. Effect of herbicides on net photosynthesis of rice plant (µ mol $CO_2/m^2/s$)

Treatment	7 DAH application	At flowering
2,4-D (800 g/ha)	31.53^{b}	8.34^{b}
2,4-D (1600 g/ha)	27.47^{e}	5.81^{e}
Metsulfuron-methyl + chlorimuron-ethyl (4 g/ha)	30.05^{c}	6.88^{c}
Metsulfuron-methyl + chlorimuron-ethyl (8 g/ha)	24.24^{g}	5.21^{f}
Penoxsulam (25 g/ha)	30.27^{c}	6.26^{d}
Penoxsulam (50 g/ha)	26.07^{f}	4.47^{g}
Two hand weeding at 20 and 60 DAS	31.90^{a}	9.11^{a}
Unweeded	29.76^{d}	6.15^{d}
LSD (p=0.05)	0.276	0.175

Stomatal conductance indicates the inflow and outflow of CO_2 and H_2O through stomata. Under stress condition, the closure of stomata occurs as a defence mechanism against loss of water and increasing stomatal resistance consequently decreases the stomatal conductance (Taiz and Zeiger 2009). In the present experiment, the stomatal conductance was adversely affected by herbicide application compared to handweeded control (**Table 5**). Double the recommended dose reduced the stomatal conductance which became lower even than the unweeded control. Agostinetto *et al.* (2016) also observed that post-emergence herbicides application caused a decrease in photosynthetic rate and stomatal conductance. Zabalba *et al.* (2006) reported that application of ALS inhibiting herbicide (imazethapyr) reduced stomatal conductance, which caused a reduction in nitrogen uptake by roots.

Table 5. Effect of herbicides on stomatal conductance of rice plant (mol $H_2O_2/m^2/s$)

Treatment	7 DAH application	At flowering
2,4-D (800 g/ha)	1.63^{b}	0.467^{b}
2,4-D (1600 g/ha)	1.14^{e}	0.306^{f}
Metsulfuron-methyl + chlorimuron-ethyl (4 g/ha)	1.52^{d}	0.394^{c}
Metsulfuron-methyl + chlorimuron-ethyl (8 g/ha)	0.680^{g}	0.295^{g}
Penoxsulam (25 g/ha)	1.57^{c}	0.359^{d}
Penoxsulam (50 g/ha)	1.04^{f}	0.209^{h}
Two hand weeding at 20 and 60 DAS	1.77^{a}	0.523^{a}
Unweeded	1.50^{d}	0.313^{e}
LSD (p=0.05)	0.017	0.001

Herbicide application increased the proline content in the rice crop (**Table 6**). The increase was significantly higher in all the doses of herbicides both 7 DAH application and at the time of flowering. However among the herbicides, recommended dose of 2,4-D (0.165) only marginally increased the proline content (3.3%) while double the recommended dose of metsulfuron-methyl + chlorimuron-ethyl (0.270) led to an increase of 47%. Double the recommended dose of herbicides recorded maximum increase compared to recommended doses. Proline act as a stress marker and can be part of a defence mechanism of the plant and hence excess dosage of 2,4-D leads to increase in proline content of plants (Ivanov *et al.* 2002).

Table 6. Effect of herbicides on proline content of rice plant (mg/g)

Treatment	7 DAH application	At flowering
2,4-D (800 g/ha)	0.165^{e}	0.175^{e}
2,4-D (1600 g/ha)	0.243^{b}	0.250^{b}
Metsulfuron-methyl + chlorimuron-ethyl (4 g/ha)	0.205^{cd}	0.222^{d}
Metsulfuron-methyl + chlorimuron-ethyl (8 g/ha)	0.270^{a}	0.270^{a}
Penoxsulam (25 g/ha)	0.193^{d}	0.233^{c}
Penoxsulam (50 g/ha)	0.252^{b}	0.278^{a}
Two hand weeding at 20 and 60 DAS	0.143^{f}	0.145^{f}
Unweeded	0.210^{c}	0.237^{c}
LSD (p=0.05)	0.014	0.09

Nitrate reductase activity showed no significant difference among treatment at 7 DAH application, while at flowering, higher dose of herbicides showed the least value which was even less than unweeded control (363.33 µ mol of NO_2^- formed/gfresh weight/h). Hand weeded control (486.67 µ mol of NO_2^- formed/g Fresh weight/h) showed the maximum nitrate reductase activity. Beevers *et al.* (1963) observed that prolonged application of 2,4-D herbicide caused a reduction in nitrate reductase enzyme activity of cucumber. While, Zabalza *et al.* (2006) observed similar phenomenon with ALS inhibiting herbicides. Hence, Inhibition of N metabolism is a major impact of excess herbicide usage.

There was significant reduction in the content of total aminoacid of rice crop when estimated on the 7 DAH application in the present study (**Table 8**). The reduction was more in the case of ALS inhibiting herbicides such as metsulfuron-methyl + chlorimuron-ethyl (8.97 mg/g) and penoxsulam (9.11 mg/g) as compared to 2,4-D (9.89 mg/g). When the herbicides were applied at double the recommended dose, they further reduced the aminoacid content in the leaves.

Table 7. Effect of herbicides on activity of nitrate reductase enzyme of rice plant (µ mol of NO_2^- formed/g fresh weight/h)

Treatment	7 DAH application	At flowering
2,4-D (800 g/ha)	500.00	430.00^{b}
2,4-D (1600 g/ha)	433.33	203.33^{e}
Metsulfuron-methyl + chlorimuron-ethyl (4 g/ha)	446.67	386.67^{c}
Metsulfuron-methyl + chlorimuron-ethyl (8 g/ha)	410.00	203.33^{e}
Penoxsulam (25 g/ha)	460.00	363.33^{d}
Penoxsulam (50 g/ha)	463.33	190.00^{e}
Two hand weeding at 20 and 60 DAS	506.67	486.67^{a}
Unweeded	313.33	363.33^{d}
LSD (p=0.05)	Non-significant	14.74

Table 8. Effect of herbicides on total aminoacid content of rice plant (mg/ g)

Treatment	7 DAH application	At flowering
2,4-D (800 g/ha)	9.89^{ab}	8.84
2,4-D (1600 g/ha)	8.70^{c}	8.09
Metsulfuron-methyl + chlorimuron-ethyl (4 g/ha)	8.97^{bc}	8.67
Metsulfuron-methyl + chlorimuron-ethyl (8 g/ha)	8.50^{c}	7.82
Penoxsulam (25 g/ha)	9.11^{bc}	8.43
Penoxsulam (50 g/ha)	8.56^{c}	7.62
Two hand weeding at 20 and 60 DAS	10.77^{a}	9.07
Unweeded	8.77b^{c}	8.26
LSD (p=0.05)	1.163	Non-significant

The reduction in nitrate reductase enzyme activity and total aminoacid content might be the major reasons for the reduction in total soluble protein content of rice plants (**Table 9**). The data indicated the reduction in soluble protein content as compared to the hand weeded control (21.17 and 13.92 mg/g) both at one week after herbicide application and at the time of flowering. Excess dosage of the herbicides caused higher inhibition as compared to the recommended dosages.

In the present study, the activity of catalase enzyme was found to increase in the herbicide applied plots compared to handweeded plot and the data has been presented in **Table 10**. Catalase is an enzyme that coverts H_2O_2 produced by superoxide dismutase (SOD) to H_2O and O_2. At one week after herbicide application 2,4-D (14.96 units/g) showed low catalase content which was at par with hand weeded control (18.68 units/g), while at flowering stage all the treatment plots showed an increase in the catalase enzyme activity compared to hand weeded control (47.83 units/g). The oxidative stress imparted by the

Table 9. Effect of herbicides on soluble protein content of rice plant (mg/g)

Treatment	7 DAH application	At flowering
2,4-D (800 g/ha)	19.83^{b}	11.42^{b}
2,4-D (1600 g/ha)	18.00^{e}	10.08^{e}
Metsulfuron-methyl + chlorimuron-ethyl (4 g/ha)	19.50^{c}	10.83^{c}
Metsulfuron-methyl + chlorimuron-ethyl (8 g/ha)	16.25^{f}	09.00^{f}
Penoxsulam (25 g/ha)	19.50^{d}	10.50^{d}
Penoxsulam (50 g/ha)	16.91^{f}	09.00^{f}
Two hand weeding at 20 and 60 DAS	21.17^{a}	13.92^{a}
Unweeded	19.25^{d}	10.50^{d}
LSD (p=0.05)	0.400	0.232

Table 10. Effect of herbicides on activity of catalase enzyme of rice plant (Units of enzyme/g)

Treatment	7 DAH application	At flowering
2,4-D (800 g/ha)	14.96^{ef}	50.77^{g}
2,4-D (1600 g/ha)	20.09^{c}	64.83^{c}
Metsulfuron-methyl + chlorimuron-ethyl (4 g/ha)	18.57^{cd}	53.95^{f}
Metsulfuron-methyl + chlorimuron-ethyl (8 g/ha)	27.31^{a}	69.81^{b}
Penoxsulam (25 g/ha)	17.33^{de}	56.89^{e}
Penoxsulam (50 g/ha)	23.93^{b}	73.21^{a}
Two hand weeding at 20 and 60 DAS	13.43^{f}	47.83^{h}
Unweeded	18.68^{cd}	60.97^{d}
LSD (p=0.05)	2.586	2.610

herbicides led to such increase in activity of scavenging enzyme in the plant (Piexoto *et al.* 2008).

One week and one month after herbicide application, double the recommended dose of herbcides reported higher weed control efficiency (**Table 11**). Among the herbicides, double the recommended dose of 2,4-D showed maximum weed control efficiency and recommended dose of penoxsulam showed the least weed control efficiency. This was validated by Singh (2005). They reported that post-emergence application of 2,4-D at 500g/ha recorded highest weed control efficiency.

Grain yield was highest in hand weeded plot which was at par with recommended dose of 2,4-D and metsulfuron-methyl + chlorimuron-ethyl (**Table 12**). In the present study, double the recommended dose of herbicides contributed to 22-33% reduction in grain and 19-23% reduction in straw yield, respectively. Antralina *et al.* (2015) reported that among the herbicides penoxsulam-cyhalofop-butyl, bispyribac-sodium and 2,4-D + methyl metsulfuron, application of 2,4-D + methyl metsulfuron recorded a similar grain and straw yield with hand weeded control.

Table 11. Effect of herbicides on weed control efficiency (%)

Treatment	7 DAH application	At flowering
2,4-D (800 g/ha)	96.85[a]	77.81[b]
2,4-D (1600 g/ha)	99.42[a]	95.37[a]
Metsulfuron-methyl + chlorimuron-ethyl (4 g/ha)	87.64[ab]	57.52[de]
Metsulfuron-methyl + chlorimuron-ethyl (8 g/ha)	96.53[a]	73.79[bc]
Penoxsulam (25 g/ha)	77.17[b]	53.87[e]
Penoxsulam (50 g/ha)	91.24[a]	65.28[cd]
Two hand weeding at 20 and 60 DAS	100[a]	96.63[a]
Unweeded	-	-
LSD (p=0.05)	12.909	10.748

Table 12. Effect of herbicides on rice yield (t/ha)

Treatment	Grain yield	Straw yield
2,4-D (800 g/ha)	4.35[ab]	5.55[a]
2,4-D (1600 g/ha)	3.49[d]	4.56[e]
Metsulfuron-methyl + chlorimuron-ethyl (4 g/ha)	4.22[ab]	5.34[b]
Metsulfuron-methyl + chlorimuron-ethyl (8 g/ha)	3.43[d]	4.48[ef]
Penoxsulam (25 g/ha)	4.10[bc]	5.03[c]
Penoxsulam (50 g/ha)	3.01[e]	4.36[f]
Two hand weeding at 20 and 60 DAS	4.49[a]	5.65[a]
Unweeded	3.78[cd]	4.77[d]
LSD (p=0.05)	0.370	0.164

Our study indicated that plants are subjected to stress by the application of these chemicals and to overcome this, stress relieving mechanism are activated which operate at the expense of primary metabolism. Double the recommended dose of herbicides recorded higher weed control efficiency compared to its recommended doses, but it reduced the yield significantly which was even lower than the unweeded control. The recommended dose of 2,4-D, metsulfuron-methyl + chlorimuron-ethyl and penoxsulam were less harmful to the plant and the plants were able to recover within a month of application so that the yield was not significantly affected.

REFERENCES

Agostinetto D, Perboni LT, Langaro AC, Gomes J, Fraga DS and Franco JJ. 2016. Changes in photosynthesis and oxidative stress in wheat plants submmited to herbicides application. *Planta Daninha* **34**(1): 1–9.

Antralina M., Istina IN and Simarmata T. 2015. Effect of difference weed control methods to yield of lowland rice in the SOBARI. *Procedia Food Science* **3**: 323–329.

Barber JM. 1980. Catalase and peroxidase in primary leaves during development and senescence. *Zeitschriftfur Pflanzenphysiologie* **97**: 135–144.

Bates L,Waldren RP and Teare ID. 1973. Rapid determination of free proline for water-stress studies. *Plant and Soil* **39**: 205–207.

Beevers L, Peterson DM, Shannon, JC and Hageman RH. 1963. Comparative effects of 2,4-dichlorophenoxyacetic acid on nitrate metabolism in corn and cucumber. *Plant Physiology* **38**(6): 675.

Hageman RH and Flesher D. 1960. Nitrate reductase activity in corn seedlings as affected by light and nitrate content of nutrient media. *Plant Physiology* **35**(5): 700–708.

Hiscox JDand Israelstam GF. 1979. A method for the extraction of chlorophyll from leaf tissue without maceration. *CanadianJournal of Botany* **57**: 1332–1334.

Ivanov S, Alexieva V and Karanov E. 2002. Effect of prolonged action of sub-herbicide concentrations of 2,4-D on the growth and some stress markers of pea (*Pisumsativum* L.) plants. *ComptesRendus de l'AcademieBulgare des Sciences* **55**(1): 1–89.

Lowry OH, Rosebrough NJ, Farr ALand Randall RJ. 1951. Protein measurement with the folin phenol reagent. *Journal of Biological Chemistry* **193**: 265–275.

Machackova I and Matschke J. 2002. Changes in the content of indole-3-acetic acid and cytokinins in spruce, fir and oak trees after herbicide treatment. *BiologiaPlantarum* **45**(3): 375–382.

Mani VS, Malla ML and Gautam KC. 1973. Weed-killing chemicals in potato cultivation. *Indian farming* 24: 353–360.

Matringe M, Camadro JM, LabbeP and Scalla R. 1989. Protoporphyrinogen oxidase as a molecular target for diphenyl ether herbicides. *Biochemical Journal* **260**(1): 231–235.

Moore Sand Stein WH. 1948. Photometric ninhydrin method for use in the chromatography of aminoacids. *Journal of Biological Chemistry* **176**: 367–388.

Nicholas JC, Harper Jand Hageman RH. 1976. Nitrate reductase activity in Soybeans (*Glycine max* L.). *Plant Physiology* **58**: 736.

Parthasarathy K,Balu DRC and Rao PS. 1970. Studies on sandal spur. VII. Polyphenol oxidase activity and metabolism of sandal in healthy and diseased. *Proceedings of the Indian Academy of Sciences* **72**: 277–284.

Peixoto FP, Gomes-Laranjo J, Vicente JA and Madeira VM. 2008. Comparative effects of the herbicides dicamba, 2,4-D and paraquat on non-green potato tuber calli. *Journal of Plant Physiology* **165**(11): 1125–1133.

Ralph P, Haynes D, Prange J and Dennison B. 2000. The impact of the herbicide diuron on photosynthesis in three species of tropical seagrass. *Marine Pollution Bulletin* **41**(7-12): 288–293.

Ramanarayana CV. 2014. Morpho-physiological changes in rice due to application of selected post-emergent herbicides. M.Sc (Ag) Thesis, Kerala Agricultural University, Thrissur, 64 p.

Sahoo BC, Koley N and Asit DK. 1993. Dissipation and effect of chlorophenoxy herbicides on plant pigments and carbohydrates of rice plant (*Oryza sativa* L.). *Pesticide Research Journal* **5**(2): 186–191.

Singh G. 2005. Integrated weed management in direct seeded rice. In : Singh Y, Singh VP, Singh P, Singh B, Hardy DE, Johnson S and Mortimer M. (eds.), *Direct Seeding of Rice and Weed Management in the Irrigated Rice-wheat Cropping System of the Indo Gangetic Plains,* Directorate of Experiment Station, G. B. Pant University of Agriculture and Technology, Pantnagar, India, 15p.

Song NH, Yin XL, Chen GF and Yang H. 2007. Biological responses of wheat (*Triticum aestivum*) plants to the herbicide chlorotoluron in soils. *Chemosphere* **68**: 1779–178.

Taiz L and Zeiger E. 1991. *Plant Physiology*. Redwood city, CA: The Benjamin/Cummings Publishing Company, Inc. pp 92–95.

Taiz L and Zeiger E. 2009. *Plant Physiology (4th Ed.)*. Redwood city, CA: The Benjamin/Cummings Publishing Company, Inc. 819 p.

Tejada PJ, CatalinaA, Gonzalez MR and Martín P. 2013. Relationships between net photosynthesis and steady-state chlorophyll fluorescence retrieved from airborne hyperspectral imagery. *Remote Sensing of Environment* **136**: 247–258.

Zabalza A, Orcaray L, Gaston S and Royuela M. 2006. Carbohydrate accumulation in leaves of plants treated with the herbicide chlorsulfuron or imazethapyr is due to a decrease in sink strength. *Journal of Agriculturaland food chemistry* **52**(25): 7601–7606.

Zhou Q, Liu W, Zhang Y and Liu KK. 2007. Action mechanisms of acetolactate synthase-inhibiting herbicides. *Pesticide Biochemistry and Physiology* **89**(2): 89–96.

Indian Journal of Weed Science **52**(3): 276–279, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Integrated weed management with brown manuring and herbicides in dry-seeded rice

Sneha Kumari*, Tarundeep Kaur and Makhan S. Bhullar

Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab 141 001, India

**Email: snehak723@gmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00053.2

Type of article: Research note

Received : 29 March 2020
Revised : 17 July 2020
Accepted : 22 July 2020

Key words

Brown manuring

Herbicides

Sequential application

Weed dynamics

ABSTRACT

The study was carried out in rainy season in 2015 at Ludhiana, India. Present study evaluated the effect of timing of brown manuring with *Sesbania aculeata* alone and its integration with herbicides on weed incidence and rice grain yield. *Sesbania* seed was broadcasted at time of rice sowing and brown manured using 2,4-D at 580 g/ha at 4- and 5-weeks age. BM plots had significantly lower weed density and biomass than without BM (sole rice). BM at 4 weeks was more effective in suppressing weeds than BM at 5 weeks age. Among weed control methods, sequential application of pendimethalin and bispyribac gave best weed control and highest rice grain yield. Combination treatments of BM (4 weeks) with pendimethalin and, sole rice with pendimethalin and bispyribac gave similar rice grain yield. It was concluded that BM has weed control potential equivalent to one post-emergence herbicide, however, for getting the highest rice productivity it must be used in combination with pre- and post-emergence herbicides.

Dry-seeded rice (DSR) is a mechanized system of rice establishment. It has less human labour and water requirement as compared to conventional system of rice establishment (transplanting rice seedlings in puddled soils). In North-West Indo-Gangetic Plains (IGP), water table has been declining at an alarming rate of 0.1–1.0 m per year which has mainly been attributed to puddled transplanted rice (PTR) (Bhat *et al.* 2016). Less availability of farm labour owing to increasing urbanization, and higher labour costs make rice transplanting a costly affair, and in many cases rice transplanting is delayed.

Any change in establishment method changes weed composition. DSR is more prone to infestation with diverse weed flora than PTR in which ponded water provide complete check over aerobic weeds and fair control of typical rice weeds (Bhullar *et al.* 2016). Higher yield penalty in DSR is attributed to initial flush of weeds which is controlled by continuous flooding in PTR (Rao *et al.* 2007, Chauhan 2012, Singh *et al.* 2014, Singh *et al.* 2016). Under these situations, a single weed control approach is not sufficient to keep the weeds under check and avoid economic losses. Therefore, adoption of integrated weed management (IWM) practices is essential for weed management in DSR. Singh *et al.* (2018) recorded better control of weeds and higher DSR yield under integrated use of stale seed bed and post-sowing herbicides than either of two methods used alone. Anitha *et al.* (2012) observed that concurrent growing of *Sesbania* and its incorporation at 30 DAS resulted decline in total weed count due to concurrent growing of *Sesbania* was 72%, while that in weed dry matter production was 57% compared to rice grown alone. Present study investigated effect of timing of brown manuring (with *Sesbania aculeata*) and herbicides on weeds incidence, growth and yield of DSR

The field experiment was conducted in rainy season in 2015 at Research Farm, Department of Agronomy, Punjab Agricultural University (PAU), Ludhiana ($30^0 54'$ North latitude, $75^0 48'$ East longitude, 247 m). The meteorological data have showed that average maximum weekly temperature ranged between 28.7^0C to 44.5^0C. The total amount of rainfall received during the crop season was 441.70 mm, whereas; mean relative humidity varied between 27 to 85%. The total sunshine hours varied between 1.7 to 11.7 hours during the crop season. Experimental soil type was sandy loam with 0.39% organic C with pH 8.0, low in available N (243 kg N/ha) and available P (8.8 kg/ha), and high in available K (337 kg/ha).The experiment was laid out in a factorial randomized complete block design with four replications. Twelve treatments included three brown manuring (BM)-(without BM rice sole, BM at 4 weeks; BM at 5 weeks after sowing) and four weed control (pendimethalin 750 g/ha as pre-emergence (PE), bispyribac-sodium 25 g/ha as post-emergence (PoE), pendimethalin 750 g/ha as PE followed by bispyribac-sodium 25 g/ha as PoE, unsprayed check) treatments. Pendimethalin was sprayed in the evening on the day of sowing while bispyribac-sodium was sprayed when weeds were at 3-4 leaf stage. The herbicides were sprayed with a knapsack sprayer fitted with flat fan nozzle using 500 and 375 litres of water/ha for pre- and post-emergence herbicide, respectively. In rice sole, weeds were not removed. The gross plot size was 9 × 2.3 m= 20.7 m^2.

The field was ploughed once with disc harrow and cultivated twice with tractor drawn cultivator followed by planking. The field was then levelled with laser land leveller and layout was done. Rice seed was then air dried under shade to facilitate sowing and seeded directly in moist soil 20 kg/ha in rows spaced at 20 cm in 2-3 cm depth using an inclined-plate seed drill on 15^{th} June, 2015. *Sesbania* seed at 25 kg/ha was broadcast just before sowing of rice and brown manured with 2,4-D amine at 580 g/ha at 4 and 5 weeks after sowing. Nitrogen at 150 kg/ha was applied through urea, in three equal splits, at 2, 5 and 9 weeks after sowing. The whole dose of 30 kg/ha P (in the form of single super phosphate) and 30 kg/ha K (in the form of muriate of potash) were applied at the time of field preparation as basal dose. Zn at 62.5 kg/ha was applied two weeks after sowing. The crop was sprayed with 1% Fe solution (250 L/ha) at 2, 4 and 6 weeks after sowing, to prevent iron deficiency. Experimental plot was irrigated twice weekly during first two weeks to keep seed zone moist under hot dry conditions during that period. Thereafter, irrigations were applied at 7-10 days interval depending upon rainfall and last irrigation was given 12 days before crop harvest. For control of termites, chlorpyriphos 20 EC was applied at 50 g/ha by mixing with 150 kg dry sand in moist field. Leaf folder was controlled with spray of chlorpyriphos 20 EC at 50 g/ha in 250 litres of water/ha at 75 days age and propiconazole 25 EC at 62.5 g/ha was used at 90 days age to control sheath blight. The crop was harvested manually on 21^{st} October 2015. Data on number of grains per panicle and grain weight per panicle was recorded from ten representative plants per plot. Grain and straw yield were recorded from the net plot area (7 × 1.9 m= 13.3 m^2) in the centre of each plot. The harvested crop was threshed manually. The grain yield was recorded in kilograms/plot and expressed as t/ha at 14% grain moisture content.

Data on major weed density and dry biomass were recorded at 60 days after sowing (DAS), quadrate (40 × 40 cm size) was placed at two representative places in each plot. Weeds were recorded species wise and weed biomass for grass, sedge and broad-leaf weeds. Weed samples were oven dried at 70°C for constant dry biomass. All data were analyzed by factorial RBD using the SAS Proc GLM (SAS 9.3). The comparisons were made at 5% level of significance by using duncun's multiple range test (DMRT). Data were analyzed using analysis of variance (ANOVA) to evaluate the differences among treatments while the means were separated using the least significant difference (LSD) test at the 5% level of significance. Weed density and biomass data were subjected to square root transformation; however, it did not improve the homogeneity of variance. Therefore, original values were used in ANOVA.

Effect on weeds

Predominant weed species in experimental field consisted of *Echinochloa colona* L., *Dactyloctenium aegyptium* (L.) Wild, *Eleusine indica* L. among grassy weeds and *Cyperus rotundus* L., *Cyperus iria* L. among sedges. Grass weeds and *C. rotundus* appeared during initial crop growth stages and *C.iria* emerged late after *C. rotundus*. Few broad-leaved weed species, *viz., Phyllanthus niruri, Alternanthera* sp. and *Digera arvensis* were recorded but with very low densities (<5%). At 60 day, rice + BM at 4/5 weeks had lower densities of *E. colona, D. aegyptium*, *C. rotundus, C. iria* and total weed density than sole rice; BM at 4 weeks had similar grass weed density but lower density of sedges (*C. rotundus* and *C. iria*) and total weed density than BM at 5 weeks (**Table 1**). Among weed control, pendimethalin and bispyribac combination had lower density of all weed species than when herbicides used alone and unsprayed check, in both years. Bispyribac plots had lower density of *E. colona, C. rotundus, C. iria* and total weed density than pendimethalin and unsprayed check. Pendimethalin plots had lower density of all grass weeds and total weed density but had similar density of sedges compared to unsprayed check; compared to bispyribac, it had lower density of aerobic grass weeds *D. aegyptium* and *D. sanguinalis*. Pendimethalin and bispyribac sequence was more effective in reducing weed density than used alone, and reduced density of grass weeds to zero under rice + BM (4 and 5 WAS).

Effect on crop

Among BM treatments, rice + BM at 4/5 weeks had similar panicle density, grain weight/ panicle

(**Table 2**). Both these BM treatments had higher values of all these yield parameters than sole rice. Among weed control, unsprayed control had lower panicle density, and weight/panicle than pendimethalin and bispyribac applied alone or in sequence. Among herbicides, panicle density, grain weight/panicle were the highest under sequential application of pendimethalin and bispyribac and these values were higher than when herbicides used alone and unsprayed check.

Rice panicle had the highest grain weight under combination of rice + BM at 4 weeks, pendimethalin and bispyribac (**Table 2**). Grain weight under this treatment combination was similar to combination of both herbicides under sole rice or rice + BM at 5 weeks, pendimethalin or bispyribac alone under rice + BM at 4 or 5 weeks.

In case of rice grain yield, among BM treatments, rice + BM at 4/5 weeks gave higher grain yield than sole rice while rice + BM at 4 weeks gave higher yield than rice + BM at 5 weeks (**Table 2**). Among weed control, all herbicidal treatments gave higher grain yield than unsprayed control. Sequential application of pendimethalin and bispyribac gave higher grain yield than when these herbicides used alone while pendimethalin alone gave higher grain yield than bispyribac used alone.Integration of rice + BM at 4 weeks with sequential application of pendimethalin and bispyribac gave the highest grain yield which was higher than all other treatment combinations. Integration of rice + BM at 4 weeks with pendimethalin gave rice grain yield similar to when sole rice and rice + BM at 5 weeks were raised with sequential application of pendimethalin and bispyribac.

Brown manuring with *Sesbania* significantly reduced weed density and biomass without any adverse effect on DSR grain yield. The lower weed density in BM plots, as compared to sole rice, would probably be attributed to decreased availability of sunlight to germinating weed seeds which inhibited weed seed germination (Chauhan 2012).

In unsprayed control, higher grain yield under brown manuring as compared to sole rice was attributed to the differences in weed density and biomass. In BM treatments, *Sesbania* crop suppressed the weed emergence and growth as compared to without BM, and the rice crop had better growth environment which increased grain yield and attributes. Among BM treatment also, higher grain under BM at 4 weeks than at 5 weeks was attributed to better control of sedge weeds, as explained earlier. These results indicated that 4 week stage seems to be better than 5 weeks for getting best benefits in term of weed management. In BM treatments, the grain yield was lower under bispyribac alone compared to pendimethalin alone treatment. This indicates the importance of early season weed control in DSR. Pendimethalin gave effective control of grass weeds during initial crop growth stages and BM provided effective control of sedges and broad-leaf weeds. In case of bispyribac alone, higher weed growth particularly of grassy weeds provided competition to crop during initial stages which was reflected in lower grain yield. These results indicated the importance of integration of pre- than post-emergence herbicide along with BM. However, under both BM treatments, the integration of both pre- and post-emergence herbicides enhanced grain yield as compared to pre- or post-herbicides alone. These

Table 1. Effect of brown manuring and herbicide treatments on density of different weed species in direct-seeded rice (60 days after sowing) in 2015

Treatment	Weed density (no./m^2) [a,b]					Weed biomass (g/m^2) [a, b]			
	Echinochloa colona	*Dactyloctenium aegyptium*	*Cyperus rotundus*	*Cyperus iria*	Total weed density	Grass	Broad-leaf weeds	Sedges	Total weeds
Brown manuring (BM)									
Rice sole	10a	13a	185a	15a	248a	53a	13a	241c	312a
Rice + BM (4WAS)	3b	4b	83c	7c	105c	18b	2b	72a	91c
Rice + BM (5WAS)	3b	4b	117b	9b	142b	18b	1b	149b	168b
Herbicide									
Unsprayed controls	12a	12a	186a	15a	252a	61a	15a	253a	330a
Pendimethalin 750 g/ha	6b	4b	151a	13a	191b	20c	5b	174b	199bc
Bispyribac 25 g/ha	4c	11a	101b	8b	139c	56ab	1c	98c	155bc
Pendimethalin 750 g/ha *fb* bispyribac 25 g/ha	0d	1c	69c	6c	76d	2d	0c	58c	59d
Interaction	S	S	S	S	S	S	NS	S	S

[a]Means presented within each column with no common letter (s) are signiûcantly different according to Fisher's Protected least significant difference (LSD) test where P<0.05.

[b]Data were square root transformed before analysis; however, back-transformed actual mean values are presented based on the interpretation from the transformed data.

Table 2. Interaction effect of brown manuring and herbicides on yield attributes and rice grain yield

Treatment	Grain weight/ panicle (g)				Panicle density (no. /m^2)				Grain yield (t/ha)			
	Rice sole	Rice + BM (4WAS)	Rice+ BM (5WAS)	Mean	Rice sole	Rice + BM (4WAS)	Rice+ BM (5WAS)	Mean	Rice sole	Rice + BM (4WAS)	Rice+ BM (5WAS)	Mean
Unsprayed control	0.98d	2.34b	3.17ab	2.17c	94h	148e	199fg	147d	1.37hi	3.36f	3.37g	26.84d
Pendimethalin750 g/ha	3.16b	3.52ab	3.32ab	3.34ab	186ef	274bc	229cde	230b	3.71ef	5.20bc	4.56d	44.94b
Bispyribac 25 g/ha	2.10c	3.31ab	3.30ab	2.91b	120gh	228cde	217de	188c	2.68gh	4.06e	4.01e	35.86c
Pendimethalin 750 g/ha *fb* bispyribac 25 g/ha	3.62ab	3.79a	3.44ab	3.62a	290b	355a	252bcd	299a	5.47b	5.97a	4.78cd	54.02a
Mean	2.47b	3.31a	3.24a		172b	251a	224a		33.09c	46.39a	41.77b	

[a]Means presented within each column with no common letter(s) are significantly different according to Fisher's Protected least significant difference (LSD) test where P<0.05; WAS - Week after sowing

results indicated the need for post-emergence herbicide also, along with pre-emergence for achieving the best DSR yield. The critical periods in case of DSR are longer (Singh *et al*. 2014) which supports our results in that combination of BM and pre- and post-emergence herbicides were able to maintain effective control of broad spectrum of weeds over longer period and hence gave the highest grain yield. Pendimethalin and bispyribac complement each other; pendimethalin is effective against annual aerobic grass weeds and bispyribac against typical grass, broadleaf and sedge weeds of rice but does not control *D. aegyptium* (Chauhan 2011, Gopal *et al*. 2010). In our case also, pendimethalin recorded effective control of grass weeds especially aerobic grasses and follow up application of bispyribac effectively controlled typical grass weeds of rice, broadleaf and sedges. Hence, the sequential application of pendimethalin as pre- and bispyribac as post-emergence provides broad spectrum control of weeds, which was true in this case also, hence the rice grain yield under combination treatment was higher as compared to when these herbicides used alone, both under sole rice and BM treatments.

Conclusions

In dry- seeded rice, brown manuring (BM) with *Sesbania aculeata* reduced weed density and biomass than sole rice; BM at 4 weeks provided higher level of weed suppression than BM at 5 weeks. Among herbicides, pendimethalin 750 g/ha as pre- and bispyribac-sodium 25 g/ha as post-emergence gave the highest rice grain yield and reduced weed density and biomass as compared to pendimethalin and bispyribac applied alone.

REFERENCES

Anitha S, Mathew J and Abraham CT. 2012. Concurrent growing of green manure with wet-seeded rice for cost-effective weed management, *Indian Journal of Weed Science* **44**(1): 34–37.

Bhat R, Kukkal S, Mutiu AB, Arora S and Yadav M. 2016. Sustainability issues on rice– wheat cropping system. *International Journal of Soil Water Conservation Research* **4**: 64–74.

Bhullar MS, Kumar S, Kaur S, Kaur T, Singh J, Yadav R, Chauhan BS, Gill G. 2016. Management of complex weed flora in dry-seeded rice. *Crop Protection* **83**: 20–26.

Chauhan BS. 2011. Crow foot grass (*Dactyloctenium aegyptium*) germination and response to herbicides in the Philippines. *Weed Science* **59**: 512–516.

Chauhan BS. 2012. Weed ecology and weed management strategies for dry-seeded rice in Asia. *Weed Technology* **26**: 1–13.

Gopal R, Jat RK, Malik RK, Kumar V, Alam MM, Jat ML, Mazid MA, Saharawat, YS, McDonald, and Gupta R. 2010. Direct dry seeded rice production technology and weed management in rice based systems. *Technical Bulletin*. International Maize and Wheat Improvement Center, New Delhi, India, 28pp.

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

Singh Manpreet , Bhullar MS and Gill G. 2018. Integrated weed management in dry seeded rice using stale seed bed and post sowing herbicides *Field Crops Research* **224**: 182–191.

Singh M, Bhullar MS, Chauhan BS. 2014. The critical period for weed control in dry-seeded rice *Crop Protection* **66**: 80–85.

Singh VP, Singh SP, Dhyani VC, Banga A, Kumar A, Satyawali K. 2016.Weed management in direct-seeded rice. *Indian Journal Weed Sciences* **48(3)**: 233–246.

Indian Journal of Weed Science **52**(3): 280–282, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Biochar and herbicide application effect on weed dynamics and yield of dry direct-seeded rice

Suprava Nath*, V.C. Dhyani, V. Pratap Singh, Sumit Chaturvedi, Subhashisa Praharaj and Arya Kumar Sarvadamana

G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand 263 145, India

**Email: supravanath96@gmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00054.4

Type of article: Research note

Received : 30 March 2020
Revised : 11 August 2020
Accepted : 13 August 2020

Key words
Biochar
Dry direct-seeded rice
Weed
Yield

ABSTRACT

Field experiment was conducted during rainy season *(Kharif)* 2018 to study the bio-efficacy of pre-emergence herbicides in dry direct-seeded rice. The treatments were weedy check, weed free, pendimethalin applied as pre-emergence at 1.0, 1.5 and 2.0 kg/ha *fb* post-emergence application of bispyribac-sodium at 0.025 kg/ha with amendment of biochar at 4.0 t/ha and without amendment of biochar. Total weed dry matter accumulation was maximum at 60 DAS. The highest grain yield was obtained in weed free treatment which was 7.38% higher than pendimethalin as pre-emergence at 1.5 kg/ha followed by bispyribac-sodium at 25 g/ha under biochar condition. Recommended dose of pendimethalin (1.0 kg/ha) along with biochar had 7.5% less yield compared to 1.0 kg/ha pendimethalin without biochar amendment. Higher dose of pendimethalin reduced grain, straw and biological yield, setback on yield was more pronounced in non-biochar amended soil. Addition of biochar decreased the B:C compared to without biochar treatments.

Direct-seeding saves irrigation water, labour and production costs, giving higher net profit (Mishra *et al.* 2016) and a reduction in methane gas emissions (Joshi *et al.* 2013) in rice. Despite these advantages, yields have been inconsistent in some regions, especially in case of dry direct-seeded condition due to uneven and unsatisfactory crop stand, poor weed control, crop lodging, and faulty management of water and nutrient (Kumar and Ladha 2011). Gharde *et al.* (2018) reported that economic losses due to weeds alone, was the highest in rice amounting to 4420 million dollar annually. Weeds grow much faster than crop plants and thus utilize available soil nutrient earlier, resulting in lack of nutrients for growth and development of rice plant (Angiras and Attri 2002). Sequential spray of pre-emergence application of pendimethalin 1.0 kg/ha followed by post-emergence application of bispyribac-sodium 30 g/ha at 15-25 days after sowing was found the best for the control of weeds in DSR (Mahajan *et al.* 2009). Management of rice residues after combine harvest is becoming a major issue in rice-wheat system; and most farmers in the Indo-Gangetic Plains are burning these crop residues to clean the field for the next crop, and thereby increasing environmental pollution (Mishra *et al.* 2020). Among various approaches of crop residue management, thermo-chemical conversion of residue into biochar has been found as a potential strategy (Haefele *et al.* 2011). It has been recommended as a promising soil amendment because of its potential to improve soil physical, chemical and biological properties (Lehmann and Joseph 2009). However studies are lacking with respect to weed occurrence, herbicide efficacy and weed management in high herbicide dependent management system like direct-seeded rice. Hence, an experiment was undertaken to optimize the dose of pre-emergence herbicide for direct-seeded rice under biochar amended soil and to find out the density and dry matter accumulation of major weed species and to calculate weed control efficiency at different crop growth stages.

Field experiment was carried out during *Kharif* season of 2018 at G.B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand). Soil type at the experimental site was clay loam in texture, almost neutral in reaction (pH- 6.7) and medium in organic carbon (0.72%). Available N, P and K content in soil was 282.4, 25.2 and 184.5 kg/ha, respectively. Rice variety '*Pant Dhan-18*' was sown on 14^{th} June, 2018 at a row spacing of 20 cm and harvested on 15^{th} October, 2018. Crop was fertilized with 120: 60:40 kg/ha of N, P and K, respectively. Biochar was applied in the field during the last tillage operation at 4 t/ha. Pendimethalin at 1.0, 1.5 and 2.0 kg/ha were applied on the next day of sowing and bispyribac-sodium at 25 g/ha at 20 DAS using 500 litres volume of water by knapsack sprayer fitted with flat-fan nozzle. In weed free plot, weeds were removed by hand weeding as and when desired. Data on weed population and dry matter, crop growth and yield were recorded. Weed control efficiency and benefit: cost ratio was calculated. Weed data were square-root transformed before statistical analysis.

Weed population and dry matter

Echinichloa crus-galli and *E. colona* were the two dominant grasses in the experimental field contributing 17.02% and 43.77% at 60 DAS. *Trianthema portulacastrum, Cyperus rotundus* and *C. iria* were the predominant weed species during initial stages (40 DAS) contributing 17.25, 25.57 and 11.76%, respectively to the total weed population. Pendimethalin as pre-emergence (PE) at 2.0 kg/ha followed by bispyribac-sodium as post-emergence (PoE) at 25 g/ha caused highest weed reduction after weed free which was statistically at par with pendimethalin as PE at 1.5 kg/ha followed by bispyribac-sodium as PoE at 25 g/ha and pendimethalin as PE at 2.0 kg/ha followed by bispyribac-sodium as PoE at 25 g/ha under biochar condition and had significant effect over rest of the treatments at 60 DAS. At 40 DAS, pendimethalin as PE at 2.0 kg/ha followed by bispyribac-sodium as PoE at 25 g/ha caused significant reduction in total weed density compared to other treatments. Among the biochar amended treatments, pendimethalin as PE at 1.0 kg/ha followed by bispyribac-sodium as PoE at 25 g/ha under biochar condition resulted in significant higher weed density over pendimethalin as PE at 1.5 kg/ha followed by bispyribac-sodium as PoE at 25 g/ha under biochar condition and pendimethalin as PE at 2.0 kg/ha followed by bispyribac-sodium as PoE at 25 g/ha under biochar condition throughout every stages of crop growth. In biochar amended plots, the density of the weeds was more compared to no biochar amended plots as the pendimethalin got adsorbed to the larger surface area of biochar and reduced its bioavailability to the weeds ultimately affecting density. Soni *et al.* (2015) observed similar results. At all the stages of crop growth, increasing the dose of pendimethalin from 1.0 kg/ha to 2.0 kg/ha as PE *fb* bispyribac-sodium as PoE at 25 g/ha reduced the weed density and dry matter. This is due to the fact that with increasing the dose of pendimethalin there was more active ingredient and more herbicide molecules in the same area of application as of lower dose (Singh *et al.* 2005). Application of biochar resulted in higher total weed dry matter accumulation compared to no biochar at all the stages. This could be ascribed to the fact that adsorption of pendimethalin to biochar limits its activity and thus effects weed density as well as weed dry matter.

Crop growth and yield

Shoot count varied according to weed densities across the treatments. At low dose of pendimethalin *i.e.* 1.0 kg/ha as PE *fb* bispyribac-sodium as PoE at 25 g/ha crop growth was lower in biochar amended soil compared to without biochar. However, application of pendimethalin at 1.5 kg/ha as pre-emergence *fb* bispyribac-sodium as PoE at 25 g/ha led to better shoot count due to reduction in weed pressure and beneficial effect of biochar.

Biochar amended weed control treatments resulted in higher plant height, number of shoots and crop dry matter accumulation per unit area compared to no biochar treatments as application of biochar improved soil physical characteristics (*i.e.* bulk density, water holding capacity, permeability), soil chemical characteristics (*i.e.* nutrient retention, nutrient availability) and soil biological properties which resulted in better plant growth attributes. The highest grain yield was observed in weed free treatment (5.42 t/ha). This might be due to frequent hand weeding which resulted in elimination of weeds as and when required. This produced a favourable microclimate by reducing the weed competition particularly at most rapid tillering stage of rice. At the dose 1.5 kg/ha of pendimethalin as pre-emergence *fb* bispyribac-sodium as PoE at 25 g/ha, grain yield was

Table 1. Effect of different treatments on density and dry matter accumulation of total weeds at different crop growth stages

Treatment	Dose (g/ha)	Total weed density (no./m^2)			Total weed dry matter (g/m^2)		
		40 DAS	60 DAS	80 DAS	40 DAS	60 DAS	80 DAS
Biochar + pendimethalin (PE) *fb* bispyribac-sodium (PoE)	1000+25	6.5(42.6)	6.7(44.7)	6.3(39.0)	4.2(16.8)	6.8(45.6)	5.4(29.1)
Biochar + pendimethalin (PE) *fb* bispyribac-sodium (PoE)	1500+25	4.8(22.8)	5.3(28.7)	4.8(23.3)	3.1(8.9)	5.7(31.8)	3.8(14.0)
Biochar + pendimethalin (PE) *fb* bispyribac-sodium (PoE)	2000+25	3.5(12.0)	3.7(13.3)	3.4(11.3)	2.2(4.2)	4.1(15.9)	1.5(1.5)
Pendimethalin (PE) *fb* bispyribac-sodium (PoE)	1000+25	5.1(26.0)	5.4(28.7)	4.9(23.3)	3.2(9.7)	5.6(31.4)	3.9(14.8)
Pendimethalin (PE) *fb* bispyribac-sodium (PoE)	1500+25	3.4(11.6)	3.8(14.0)	3.2(9.3)	2.1(3.6)	3.9(14.3)	2.5(5.7)
Pendimethalin (PE) *fb* bispyribac-sodium (PoE)	2000+25	2.4(5.3)	3.3(10.0)	2.6(6.0)	1.6(1.7)	2.8(7.9)	1.5(1.4)
Weedy check		9.2(85.0)	10.4(109.7)	9.7(94.7)	6.3(39.2)	11.0(121.0)	8.4(70.2)
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)
LSD (p=0.05)		0.9	0.8	0.7	0.44	0.69	0.40

PE- Pre-emergence; PoE- Post-emergence; Original values are given in parentheses; DAS - Days after sowing

Table 2. Effect of different treatments on crop growth, yield attributes, yield and economics of direct-seeded rice

Treatment	Dose (g/ha)	Plant height (cm)	Number of shoots (no./m²)	Crop biomass accumulation (g/m²)	Panicles (no./ m²)	Filled grains /panicle	Grain yield (t/ha)	B:C ratio
Biochar + pendimethalin (PE) *fb* bispyribac-sodium (PoE)	1000 + 25	97	368	1270	175	115	4.03	1.23
Biochar + pendimethalin (PE) *fb* bispyribac-sodium (PoE)	1500 + 25	100	385	1312	223	128	5.02	1.83
Biochar + pendimethalin (PE) *fb* bispyribac-sodium (PoE)	2000 + 25	100	380	1308	218	123	4.80	1.64
Pendimethalin (PE) *fb* bispyribac-sodium (PoE)	1000 + 25	100	350	1310	197	119	4.36	1.90
Pendimethalin (PE) *fb* bispyribac-sodium (PoE)	1500 + 25	99	370	1306	200	123	4.80	2.00
Pendimethalin (PE) *fb* bispyribac-sodium (PoE)	2000 + 25	93	343	1263	178	107	4.07	1.56
Weedy check		88	225	245	87	89	1.00	-0.22
Weed free		103	401	1308	225	129	5.42	1.81
LSD (p=0.05)		3	47	68	21	14	0.36	

significantly higher in biochar amended treatment (5.02 t/ha) compared to no biochar treatment at the same dose (4.80 t/ha). Grain yield was more due to synergistic effect of biochar and applied nitrogen which increased the nitrogen availability and also improved soil physical properties. This result was in compliance with the findings of Asai *et al.* (2009).

Pendimethalin as PE at 2.0 kg/ha followed by bispyribac-sodium as PoE at 25 g/ha resulted lower grain yield (4.07 t/ha) compared to lower doses of application of pendimethalin (1.0 and 1.5 kg/ha) followed by bispyribac-sodium as PoE at 25 g/ha (4.36 and 4.80 t/ha, respectively). This could be ascribed to the fact that high dose of pendimethalin resulted in lesser number of shoots per unit area which led to lesser panicles per unit area and ultimately reduced number of grains per unit area. Singh *et al.* (2005) also reported that with increase in dose of pendimethalin from 1.0 kg/ha to 2.0 kg/ha as PE *fb* bispyribac-sodium as PoE at 25 g/ha, there was reduction in number of panicles per unit area which ultimately reduced the yield. B: C ratio (2.00) was higher when pendimethalin was applied at 1.5 kg/ha as PE *fb* bispyribac-sodium as PoE at 25 g/ha in without biochar herbicidal treatment compared to the same dose in biochar amended soil in spite of lower yield (1.83). Lower B:C ratio in biochar amended weed control treatments is attributed to increased cost of cultivation due to biochar. Weedy check reported negative B: C ratio due to significantly lower yield compared to other treatments.

Pendimethalin as PE at 1.5 kg/ha followed by bispyribac-sodium at 25 g/ha under biochar condition was proved best treatment both for weed control and yield obtained.

REFERENCES

Angiras NN and Attri SP. 2002. Efficacy of herbicide mixture in direct seeded puddle rice. *Indian Journal of Weed Science* **34**(1&2): 42–45.

Asai H, Samson BK, Stephan HM, Songyikhangsuthor K, Homma K, Kiyono Y, Inoue Y, Shiraiwa T and Horie T. 2009. Biochar amendment techniques for upland rice production in Northern Laos 1. Soil physical properties, leaf SPAD and grain yield. *Field Crops Research* **111**: 81–84.

Gharde Y, Singh PK, Dubey RP and Gupta PK. 2018. Assessment of yield and economic losses in agriculture due to weeds in India. *Crop Protection* **107**: 12–18.

Haefele SM, Konboon Y, Wong boon W, Amarante S, Maarifat AA and Pfeiffer EM. 2011. Effects and fate of biochar from rice residues in rice-based systems.*Field Crop Research* **121**: 430–440.

Joshi E, Kumar D, Lal B, Nepalia V, Gautam P and Vyas AK. 2013. Management of direct seeded rice for enhanced resource-use efficiency. *Plant Knowledge Journal* **2**(3): 119.

Kumar V and Ladha JK. 2011. Direct seeding of rice. Recent developments and Future Research needs. *Advances in Agronomy* **111**: 297–413.

Lehmann CJ and Joseph S. 2009.Biochar systems. pp. 207-222. In: *Biochar for Environmental Management: Science and Technology*. (Eds. Lehmann CJ and Joseph S), *Earthscan. London*.

Mahajan G, Chauhan BS and Johnson DE. 2009. Weed management in aerobic rice in north Western Indo-Gangetic plains. *Journal of Crop Improvement* **23**: 366–382.

Mishra AK, Khanal AR and Pede V. 2016. Economic and resource conservation perspectives of direct-seeded rice planting methods: Evidence from India *Proceedings of Agricultural and Applied Economics Association's 2017 AAEA Annual Meeting,* Chicago, IL, July 30-August 2, 2016.

Mishra JS, Bhatt BP, Arunachalam A and Jat ML. 2020. *Conservation Agriculture for Sustainable Intensification in Eastern India*. Policy Brief, 8p. Indian Council of Agricultural Research and National Academy of Agricultural Sciences, New Delhi.

Singh VP and Singh G. 2001. Weed control studies in spring rice under rainfed low land situation of Uttaranchal. *Indian Journal of Weed Science* **33** (1&2): 52–55.

Singh VP, Singh G, Singh RK, Singh SP, Kumar A, Dhyani VC, Kumar M and Sharma G. 2005. Effects of herbicides alone and in combination on direct seeded rice. *Indian Journal of Weed Science* **37**(3&4):197–201.

Soni N, Leon RG, Erickson JE, Ferrell JA and Silveira ML. 2015. Biochar decreases atrazine and pendimethalin pre-emergence herbicidal activity. *Weed Technology* **29**(3): 359–366.

Indian Journal of Weed Science **52**(3): 283–285, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Crop-weed competition in blackgram in coastal deltaic eco-system

P. Saravanane*, R. Poonguzhalan, S. Vijayakumar[1] and K. Pooja

Department of Agronomy, Pandit Jawaharlal Nehru College of Agriculture & Research Institute, Karaikal, Puducherry U.T. 609 603, India

[1]Crop Production Division, National Rice Research Institute, Cuttack, Odisha 753 006, India

**Email: psaravanane@rediffmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00055.6

Type of article: Research note

Received : 3 June 2020
Revised : 7 September 2020
Accepted : 11 September 2020

Key words

Blackgram

Critical period

Yield loss

Weed competition

ABSTRACT

A field experiment was carried out at Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, U.T. of Puducherry, India during rainy season (*Kharif)* of 2019 with ten treatments replicated thrice in a randomized block design to study the critical period of crop-weed competition in irrigated blackgram in deltaic coastal ecosystem. The weed spectrum comprised of *Echinochloa colona* (L), *Dactyloctenium aegyptium* (L.), *Trianthema portulacastrum (*L.), *Cleome viscosa* (L.), *Eclipta prostrata* (L.) and *Cyperus rotundus* (L.). The density and dry weight of weeds significantly increased when crop-weed competition was prolonged from 15 days after sowing (DAS) to the maturity of the crop. The highest seed yield (706.5 kg/ in coastaha) was obtained when blackgram was maintained weed free till harvest closely followed by weed free till 60 DAS (652.1 kg/ha) and weedy condition till 15 DAS (608.6 kg/ha). The critical period of crop-weed competition was found to be 17 to 50 DAS. Weedy condition upto 15, 30, 45, 60 DAS and throughout crop growth resulted in a yield loss of 9.66, 39.19, 59.13, 75.87 and 86.30%, respectively.

Blackgram (*Vigna mungo* L.) is the third most important grain legume cultivated in India accounting 12% of total pulse production. The low productivity in blackgram is attributed to numerous biotic and abiotic factors, of which, the most important factor is weed management. Blackgram experience high weed competition during rainy season *(Kharif)* (Balyan *et al*. 2016) due to favourable weather conditions associated with sufficient moisture availability which facilitate weed emergence in succession. The yield loss due to weed competition depends on the intensity and duration of competition as well as the stage of crop growth (Singh *et al*. 1991). Lack of proper weed management is found to cause upto 80% reduction in grain yield of blackgram (Kumar and Tiwari 2004). Therefore, determination of critical period of crop-weed competition is an important step to formulate weed management practices that are effective and economical to the farmers. Most of the earlier crop-weed competition studies were conducted in light soils and no studies in blackgram in heavy soils of coastal deltaic ecosystem.

A field study was conducted during rainy season (June–August 2019) at research farm of Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, Puducherry (11° 56' N latitude, 79° 53' E longitude, 4 m above mean sea level), India. The experiment was laid out in randomized block design with ten treatments. Treatments consisted of maintaining weedy conditions for the first 15, 30, 45, 60 days after sowing (DAS) and throughout crop growth and maintaining weed- free conditions for the first 15, 30, 45, 60 DAS and throughout crop growth. Blackgram cultivar '*VBN (Bg) 4*' having a duration of 80 days was manually sown adopting a seed rate of 20 kg/ha at 30 x 10 cm spacing. Weed density and weed dry weight at specified period were recorded by employing two quadrats (0.5 x 0.5 m) placed randomly in each plot. Growth parameters, yield parameters and seed yield (12% moisture content) were recorded at harvest. Experimental data were subjected to statistical analysis as per the procedures given by Panse and Sukhatme (1967) and inferences were drawn at 5% probability level. The data on weed density and dry weight were subjected to square root transformation ($\sqrt{x + 0.5}$) before statistical analysis. The Gompertz (weed free) and logistic (weedy) curves were fitted to determine the critical weed-free period at 5% acceptable yield loss level.

Effect on weeds

The experimental field was infested with diverse weed flora comprising 87.3% grasses [(*Echinochloa* *colona* (L.), *Dactyloctenium aegyptium* (L.)], 7.6% sedge (*Cyperus rotundus* (L.)) and 5.1% broad-leaf weeds (BLW) [(*Trianthema portulacastrum* (L.), *Cleome viscosa* (L.), *Eclipta prostrata* (L).]. Singh *et al*. (1991) indicated that grassy species dominated the weed spectrum in blackgram with more than 70% of the total weed density. Significant increase in weed density and dry weight of grasses, BLW and total weeds was observed when crop-weed competition was prolonged from 15 DAS to maturity of the crop (**Table 1)**. Higher density (457.3 no./m^2) and dry weight (423.1 g/m^2) of grasses was recorded in weedy plot throughout crop growth. However, the density (4.0 no./m^2) and dry weight (1.8 g/m^2) of grassy weeds was significantly decreased when weed free environment was maintained. Patzold *et al*. (2020) also indicated that grassy weeds were positively correlated with available water content of the soil. Similar trend was noticed in case of density and dry weight of BLW and total weeds also (**Table 1**).

Effect on blackgram

Significantly higher plant height (42.1 cm) was recorded when weed-free condition was maintained throughout crop growth (**Table 1**). There was 29.2% reduction in plant height, resulting in stunted blackgram plants under weedy condition throughout crop growth. Dry matter accumulation and number of pods per plant were significantly decreased with increased duration of weed competition. Significantly lower dry matter accumulation (0.65 g/plant) and pods per plant (5.4) were recorded under weedy plots. Earlier studies have also demonstrated the poor growth of blackgram under longer duration of weed competition (Kumar and Tiwari 2004).

Grain yield was significantly reduced with increase in the duration of crop-weed competition (**Table 1**). The highest blackgram yield was obtained in weed free throughout the crop period (706.5 kg/ha), closely followed by weed free till 60 DAS (652.1 kg/ha) and weedy till 15 DAS (608.6 kg/ha). Maintaining weedy condition throughout crop growth period resulted in the lowest yield (96.8 kg/ha). Weedy condition till 15, 30, 45, 60 DAS and throughout crop growth resulted in the yield loss of 9.66, 39.19, 59.13, 75.87 and 86.30%, respectively. Kumar and Tiwari (2004) reported that yield loss in blackgram was 40.1% when crop experienced weed competition throughout crop growth.

The linear regression between pods/plant and dry matter (R^2=0.78), yield and dry matter (R^2=0.77) was significant and positive (**Figures 1a and b**) while number of pods/plant and weed dry weight (R^2=0.73), yield and weed dry weight (R^2=0.74) was significant and negative (**Figures 1c and d**). The yield of blackgram decreased with increasing amount of weed dry weight. The lower yield might be due to higher physical suppression and competition with increasing intensity and duration of weed competition. The better growth and higher yield of blackgram under weed free condition shows the reduced physical suppression and competition.

Table 1. Effect of varying crop- weed competition periods on weed and crop attributes of blackgram

Treatment	Weed density (no./m^2)				Weed dry weight (g/m^2)				Plant height (cm)	DMP (g/ plant)	Pods/ plant (no.)	Grain yield (kg/ha)	Weed Index
	Grasses	Sedge	BLW	Total	Grasses	Sedge	BLW	Total					
Weedy till 15 DAS	9.87 (88)	2.06 (3.7)	3.17 (8.0)	10.46 (100)	6.20 (32.6)	1.34 (1.3)	1.68 (1.4)	6.44 (35)	40.9	5.12	32.0	608.6	13.85
Weedy till 30 DAS	16.53 (258)	2.32 (2.3)	4.32 (14.7)	17.14 (278)	13.11 (160)	1.98 (3.3)	1.69 (1.6)	13.31 (165)	36.7	3.95	30.7	429.6	39.19
Weedy till 45 DAS	18.27 (317)	4.15 (28.0)	4.44 (16.0)	19.41 (361)	16.53 (258)	2.65 (6.9)	1.78 (1.9)	16.81 (267)	34.6	2.88	16.6	288.7	59.13
Weedy till 60 DAS	20.85 (421)	5.05 (34.7)	4.75 (18.7)	22.06 (474)	18.33 (323)	3.48 (15.2)	2.02 (2.6)	18.81 (341)	30.9	2.32	10.3	170.5	75.87
Weedy throughout crop growth	21.19 (457)	5.12 (40.0)	5.57 (26.7)	22.55 (524)	20.85 (423)	4.38 (26.2)	3.12 (7.4)	21.76 (457)	29.8	0.65	5.4	96.8	86.30
Weed -free till 15 DAS	17.45 (290)	6.33 (38.7)	4.90 (20.3)	19.14 (349)	15.30 (220)	5.82 (37.8)	2.68 (5.7)	16.69 (263)	30.7	2.19	12.6	147.1	79.19
Weed -free till 30 DAS	13.07 (158)	6.09 (34.7)	4.12 (13.3)	14.82 (206)	10.53 (101)	4.86 (21.9)	1.30 (1.9)	11.64 (124)	32.3	3.96	18.9	329.6	53.35
Weed -free till 45 DAS	9.46 (81)	5.57 (29.3)	3.16 (7.3)	11.30 (117)	8.68 (68)	4.76 (18.4)	0.88 (0.4)	9.78 (87)	34.5	4.85	26.0	549.5	22.22
Weed -free till 60 DAS	8.37 (63)	4.26 (16.0)	1.91 (3.0)	9.45 (82)	7.22 (48.6)	3.65 (10.6)	0.71 (0.1)	8.03 (59)	35.1	5.86	32.0	652.1	07.70
Weed -free throughout crop growth	2.11 (4)	1.17 (1.3)	1.24 (1.7)	3.11 (7)	1.57 (1.8)	0.97 (0.7)	0.50 (0.0)	2.03 (2)	42.1	7.37	36.5	706.5	-
LSD (p=0.05)	3.16	NS	1.76	5.30	3.48	NS	1.29	2.57	6.53	1.04	5.63	120.5	

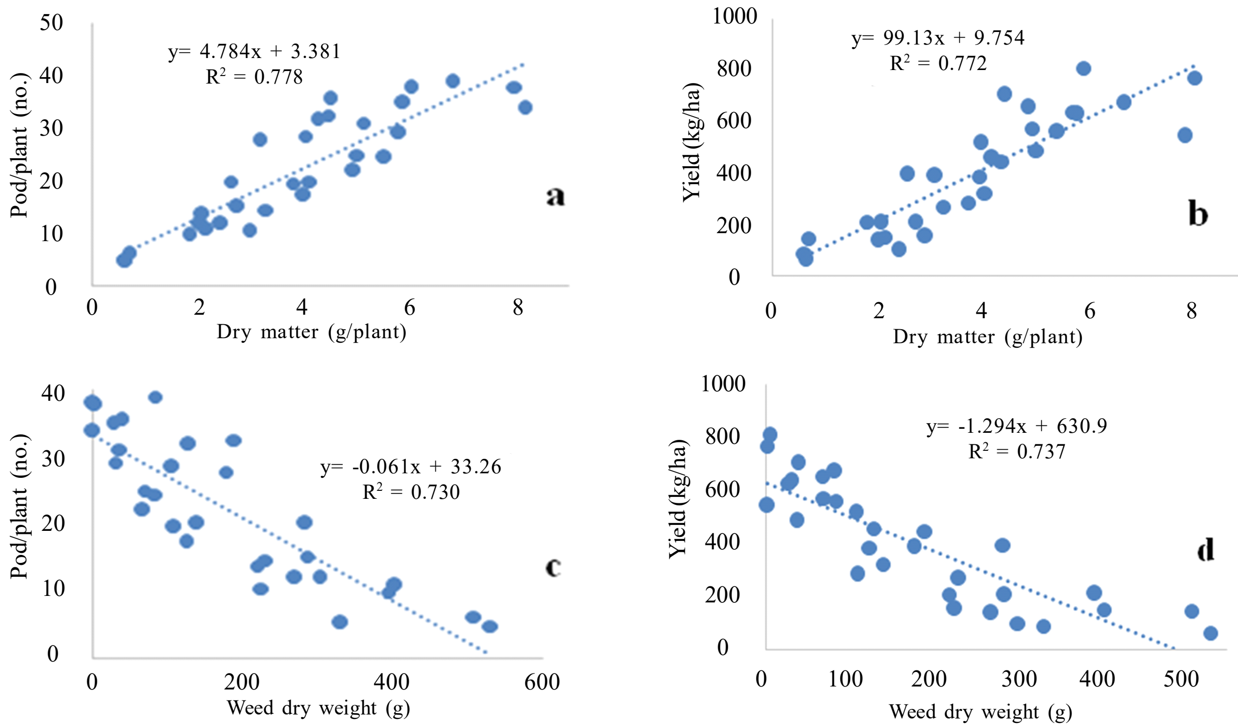

Figure 1. Simple linear regression between (a) pods/plant and dry matter of plant (b) yield and dry matter of plant (c) pods/plant and weed dry matter (d) weed dry matter and yield

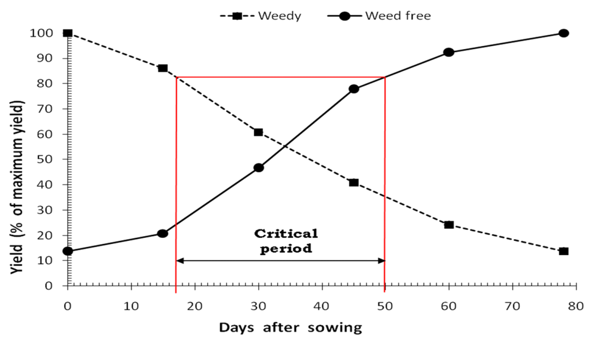

Figure 2. Critical period of crop-weed competition in irrigated blackgram

Critical period of crop- weed competition

The maximum seed yield (706.5 kg/ha) was obtained in weed free plots. Blackgram seed yield was statistically at par with maximum yield when the weedy period last up to initial 17 days and weed free period upto 50 days (**Figure 2**). Earlier studies indicated that early 20-40 days duration was critical for crop-weed competition in blackgram (Saraswat and Mishra 1993, Kumar and Tiwari, 2004). In this particular study, sandy clay loam texture of the soil with more water holding capacity might have helped the weeds to emerge in succession for longer duration. Korres *et al.* (2017) indicated that soil texture and water holding capacity influence the occurrence of the weeds for longer period.

Study revealed that the critical of crop-weed competition in blackgram cultivated in heavy soils of coastal Cauvery delta is 17 to 50 DAS. Hence, in future, extended critical period of weed competition may be considered to formulate suitable weed management methods to minimize the yield loss in irrigated blackgram.

REFERENCES

Balyan JK, Choudhary RS, Kumpawat BS and Choudhary R. 2016. Weed management in blackgram under rainfed conditions. *Indian Journal of Weed Science* **48**(2): 173–177.

Korres NE, Norsworthy JK, Brye KR, Skinner Jr V and Mauromoustakos A. 2017. Relationship between soil properties and the occurrence of the most important agronomically weed species in the field margins of eastern Arkansas- Implications for weed management in field management. *Weed Research* **57**: 159–171.

Kumar A and Tewari AN. 2004. Crop- weed competition studies in summer sown blackgram (*Vigna mungo* L.). *Indian Journal of Weed Science* **36**(1&2): 76–78.

Panse VG and Sukhatame PU 1967. *Statistical Methods for Agricultural Workers*. ICAR, New Delhi.

Patzold S, Hbirkou C, Dicke D, Gerhards R and Welp G. 2020. Linking weed patterns with soil properties: a long-term case study. *Precision Agriculture* **21**: 569–588.

Saraswat VN and Mishra JS. 1993. Weed management in pulse crops, pp. 137-140. In: *Proceedings of International Symposium, Indian Society of Weed Science, Hisar,* 18-20 November 1993.

Singh G, Ram IC and Singh D. 1991. Crop- weed competition studies in green gram and blackgram. *Pest Management* **37**(2): 144–148.

Indian Journal of Weed Science **52**(3): 286–289, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Management of *Trianthema portulacastrum* through herbicides in greengram

T. Ramesh* and S. Rathika

Department of Agronomy, Anbil Dharmalingam Agricultural College and Research Institute, Tamil Nadu Agricultural University, Tiruchirappalli, Tamil Nadu 620 009, India

**Email: agronramesh@gmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00056.8

Type of article: Research note

Received : 8 June 2020
Revised : 6 September 2020
Accepted : 9 September 2020

Key words
Economics
Greengram
Herbicides
Imazethapyr
Oxyfluorfen
Pendimethalin
Trianthema portulacastrum

ABSTRACT

Field experiments were conducted to select suitable pre- and post-emergence herbicides for the control of *Trianthema portulacastrum* in greengram. Treatments were consisted of pre-emergence (PE) herbicides, *viz*. pendimethalin (1.0 kg/ha), oxyfluorfen (100 and 200 g/ha) with one hand weeding at 30 days after sowing (DAS), post-emergence (PoE) imazethapyr 50 g/ha at 15 DAS, combinations of PE and PoE herbicides and hand weeding (HW) twice at 15 and 30 DAS and control. Significantly lesser weed density (137/m^2) and dry weight (30.4 g/m^2) and higher weed control efficiency (89.6%) were recorded with application of pendimethalin 1.0 kg/ha at 3 DAS + imazethapyr 50 g/ha at 30 DAS than other treatments at 45 DAS. Significantly higher dry matter production (1.34 t/ha), more number of pods per plant (38.4) and seeds per pod (9.8) were recorded with application of pendimethalin1.0 kg/ha + imazethapyr 50 g/ha 30 DAS than other treatments. Application of pendimethalin 1.0 kg/ha on 3 DAS followed by imazethapyr 50 g/ha on 30 DAS recorded significantly higher mean grain yield of 461 kg/ha, mean net returns (₹ 14443/ha) and benefit cost ratio (2.09) over other treatments. Thus, it could be concluded that application of PE herbicide pendimethalin 1.0 kg/ha on 3 DAS followed by PoE herbicide imazethapyr 50g/ha on 30 DAS controlled the *Trianthema portulacastrum* effectively and produced higher productivity and profitability of greengram in irrigated condition.

Horse purslane (*Trianthema portulacastrum L.*) belongs to the Aizoaceae family and is a much branched, fast growing, prostrate, succulent annual herb with ovate green leaves. It is widely distributed in India, Pakistan, Sri Lanka, West Asia, Africa, and tropical America (Saeed *et al.* 2010). Its infestation is very common in various crops, such as maize, pigeon pea, black gram, green gram, sesame, onion, cotton, soybean, and sugarcane especially during the rainy season. Its prostrate growth and profuse branching capacity help it to quickly cover the soil surface and form a green carpet (Senthil *et al.* 2009).

It is a very problematic weed in summer irrigated crops (pulses and sesame) in Cauvery delta zone, Tamil Nadu and a complete crop failure has been observed because of this weed. Hand weeding and hoeing are common practices of controlling this weed in Tamil Nadu, but this method is quite expensive and time consuming. Hand weeding becomes ineffective as new weed seeds germinate after every hoeing and affect the crop. Under these circumstances, it is essential to find out suitable PE and PoE herbicides for its effective control. Application of PoE herbicides imazethapyr + quizalofop-ethyl each at 75 g/ha registered higher weed control efficiency, grain yield, net returns and benefit cost ratio in summer irrigated black gram (Ramesh and Rathika 2016). Keeping this in view, field experiments were conducted to study the effect of PE and PoE herbicides on control of *Trianthema* under irrigated greengram.

Field experiments were conducted at Department of Agronomy, Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli during *Summer* and *Kharif*, 2016. The experimental soil was alkaline pH, low in available nitrogen, high in available phosphorus and medium in available potassium. The experiment was laid out in a randomized block design with three replications. Treatments were consisted of PE herbicides, *viz*.

pendimethalin (1.0 kg/ha), oxyfluorfen (100 and 200 g/ha) at 3 DAS along with one hand weeding at 30 DAS, pendimethalin (1.0 kg/ha) + imazethapyr 50 g/ha at 30 DAS, oxyfluorfen 100 g/ha + imazethapyr 50 g/ha at 30 DAS, oxyfluorfen 200 g/ha + imazethapyr 50 g/ha at 30 DAS, imazethapyr 50 g/ha at 15 DAS, hand weeding twice at 15 and 30 DAS and control. Greengram variety '*VBN 2*' was used for this study. Recommended seed rate (25 kg/ha) was used for sowing at 30 x 10 cm spacing. Recommended dose of fertilizer at 25: 50: 25 kg/ha NPK was applied as basal. Spraying of herbicides was done using knapsack sprayer fitted with flat fan nozzle by using a spray volume of 500 L/ha. Observations on weeds density and dry weight, growth and yield attributing characters and grain yield of greengram were recorded. Weed count was recorded by using 0.25 m^2 quadrate at four places in each plot and expressed as no./m^2. Square root transformation ($\sqrt{x+0.5}$) was used to analyze the data on weeds. Weed control efficiency was worked out on 45 DAS and expressed as the percentage. Economics of weed management was worked out by using the current market price of inputs and greengram grain. All the recorded data were analyzed statistically as per the method suggested by Gomez and Gomez (1984).

Effect on weeds

Weed species like *Trianthema portulacastrum (*71%) in broad-leaved weeds, *Echinochloa colona* (21%) in grasses and *Cyperus rotundus* (8%) in sedges were the predominant weed species found in the experimental field. Weed density and dry weight recorded at 45 DAS revealed that significantly lesser mean weed density of 137/m^2 recorded with pendimethalin at 1.0 kg/ha + imazethapyr 50 g/ha on 30 DAS, which was comparable with pendimethalin 1.0 kg/ha + HW 30 DAS (173.5/m^2) **(Table 1)**. Significantly lesser weed dry weight of 30.4 g/m^2 was registered with pendimethalin 1.0 kg/ha + HW 30 DAS than other treatments. However, it was comparable with HW twice on 15 and 30 DAS (36.4 g/m^2) and pendimethalin at 1.0 kg/ha + imazethapyr 50 g/ha on 30 DAS (41.7 g/m^2). Considerable reduction in germination of *Trianthema* under application of pendimethalin 1.0 kg/ha was the reason behind lesser weed density and dry weight.

Higher mean weed control efficiency of 89.6% was registered under application of pendimethalin 1.0 kg/ha + HW 30 DAS **(Table 1)**. This was closely followed by hand weeding twice at 15 and 30 DAS (87.6%). Application of pendimethalin1.0 kg/ha + imazethapyr 50 g/ha on 15 DAS recorded higher weed control efficiency of 85.8% than other combination of herbicides. Application of PE and PoE herbicides controlled the weeds effectively resulted in lesser weed dry weight and higher WCE. Minimum weed dry weight and higher weed control efficiency were recorded with application of pendimethalin 0.5 kg + imazethapyr 50 g/ha in cluster bean (Sangwan *et al.* 2016). The lowest WCE of 62.3% was obtained with application of imazethapyr 50 g/ha on 15 DAS. Imazethapyr did not control the grownup *Trianthema* completely and there was stunting and yellowing of leaves for two weeks and recovered after that. This was the reason behind lesser WCE. Compared to pendimethalin 1.0 kg/ha, oxyfluorfen 200 g/ha as PE herbicide showed lesser effect in controlling of *Trianthema* during both the seasons.

Table 1. Effect of herbicidal treatments on total weed density, dry weight, weed control efficiency at 45 DAS, growth parameters of greengram (pooled data of two seasons)

Treatment	Total weed density (no./m^2)	Weed dry weight (g/m^2)	WCE (%)	Plant height (cm)	DMP (t/ha)
Pendimethalin 1.0 kg/ha + HW 30 DAS	173.5 (13.2)	30.4(5.6)	89.6	35.8	1.27
Oxyfluorfen 100 g/ha + HW 30 DAS	344.0 (18.6)	48(7.0)	83.7	34.1	0.96
Oxyfluorfen at 200 g/ha + HW 30 DAS	363.5 (19.1)	49.9(7.1)	83.2	32.6	1.07
Imazethapyr 50 g/ha 15 DAS	643.5 (25.4)	111.2(10.6)	62.3	31.3	1.10
Pendimethalin 1.0 kg/ha + imazethapyr 50 g/ha 30 DAS	137.0 (11.7)	41.7(6.5)	85.8	33.9	1.34
Oxyfluorfen 100 g/ha + imazethapyr 50 g/ha 30 DAS	276.0 (16.6)	100.3(10.0)	65.9	32.7	1.09
Oxyfluorfen 200 g/ha + imazethapyr 50 g/ha 30 DAS	247.0 (15.7)	84.3(9.2)	71.3	32.0	1.17
Control	772.5 (27.8)	293.1(17.1)	-	27.4	0.40
HW twice on 15 and 30 DAS	352.5 (18.8)	36.4(6.1)	87.6	37.7	1.28
LSD(p=0.05)	1.8	1.1	-	2.6	0.07

Figures in parentheses are square root ($\sqrt{x+0.5}$) transformed values

Effect on crop growth characters

Growth characters of greengram has significantly influenced by weed management treatments. Hand weeding twice at 15 and 30 DAS produced significantly taller plants (37.7 cm) than other herbicidal treatments. However, this was comparable with pre-emergence application of pendimethalin at 1.0 kg/ha followed by one hand weeding at 30 DAS (35.8 cm). Plant height of greengram under different combination of herbicides showed comparable with each other.

Generally, treatments which received imazethapyr produced significantly shorter plants than hand weeding treatments. Control plot produced significantly shorter plants than other treatments mainly due to higher weed competition. Significantly higher DMP of 1.34 t/ha was recorded with pendimethalin1.0 kg/ha + imazethapyr 50 g/ha 30 DAS than control as well as oxyfluorfen treatments. This was comparable with hand weeding twice at 15 and 30 DAS (1.28 t/ha) and pendimethalin at 1.0 kg/a + hand weeding at 30 DAS (1.27 t/ha). This is mainly because of reduced weed competition during early stages of crop growth with the simultaneous increase in the uptake of nutrients by the crop which favoured taller plants, increased assimilation surface which enhanced the crop DMP (Patel *et al*., 2011). The control plot recorded significantly lower DMP than other treatments.

Effect on yield attributes and yield

With reference to yield attributes, significantly higher number of pods per plant (38.4) and seeds per pod (9.8) were recorded with application of pendimethalin1.0 kg/ha + imazethapyr 50 g/ha 30 DAS than other treatments **(Table 2)**. Pre-emergence application of pendimethalin at 1.0 kg/ha + hand weeding at 30 DAS and hand weeding twice at 15 and 30 DAS produced comparable with each other in terms of number of pods per plant and seeds per pod. Better control of weds under these treatments would have favoured increased source sink relationship which resulted in more yield attributing characters (Kaur *et al.* 2016, Muthuram *et al.* 2018). Minimum number of pods per plant was recorded under un-weeded control plot.

Grain yield of greengram was significantly varied with weed management practices. Application of pendimethalin 1.0 kg/ha on 3 DAS + imazethapyr 50 g/ha on 15 DAS recorded significantly higher mean grain yield of 461 kg/ha over other treatments **(Table 2)**. Pre-emergence application of pendimethalin at 1.0 kg/ha + one hand weeding at 30 DAS registered mean grain yield of 417 kg/ha. However, this was at par with hand weeding twice at 15 and 30 DAS. Post-emergence application of imazethapyr 50 g/ha on 15 DAS produced higher grain yield of 338 kg/ha over oxyfluorfen 100 g/ha + HW 30 DAS and control. This might be due to reduced weeds under pre- and post-emergence herbicides applied plots resulted in competition free environment at the critical stages of crop favoured the crop to utilize the factors for crop growth and production and enhanced the well balanced source sink capacities which attributed to the production of more DMP, number of pods/plant and number of seeds/pod compared to all other treatments and responsible for higher yield of irrigated green gram. In addition to that a uniform and good stand of the crop due to application of pre and post-emergence herbicides. These were in accordance with the earlier findings of Patel *et al*. (2011) and Chhodavadia (2014). In general, lesser grain yield was recorded in these field experiments mainly due to *sodic* nature of field soil as well as use of saline water for irrigation.

Table 2. Effect of herbicidal treatments on yield attributes, grain yield and economics of greengram (pooled data of two seasons)

Treatment	No. of pods /plant	No. of seeds/pod	Grain yield (kg/ha)	Net returns ($x10^3$ ₹/ha)	Benefit: Cost ratio
Pendimethalin 1.0 kg/ha + HW 30 DAS	33.1	9.6	417	11.50	1.85
Oxyfluorfen 100 g/ha + HW 30 DAS	26.2	9.4	296	5.00	1.39
Oxyfluorfen at 200 g/ha + HW 30 DAS	29.5	9.4	345	7.10	1.52
Imazethapyr 50 g/ha 15 DAS	29.6	9.0	338	9.25	1.84
Pendimethalin 1.0 kg/ha + imazethapyr 50 g/ha 30 DAS	38.4	9.8	461	14.44	2.09
Oxyfluorfen 100 g/ha + imazethapyr 50 g/ha 30 DAS	28.8	9.2	333	7.52	1.60
Oxyfluorfen 200 g/ha + imazethapyr 50 g/ha 30 DAS	33.1	9.4	373	9.08	1.68
Control	17.0	8.7	115	-2.60	0.73
HW twice on 15 and 30 DAS	32.3	9.3	389	5.26	1.29
LSD (p=0.05)	2.6	0.5	41		

Effect on economics

Economics of *Trianthema* weed management techniques in greengram revealed that pre-emergence application of pendimethalin 1.0 kg/ha + post-emergence application of imazethapyr 50 g/ha 30 DAS gave higher mean net returns (₹ 14443/ha) and benefit cost ratio (2.09) than other treatments **(Table 2)**. Pendimethalin 1.0 kg/ha + HW 30 DAS registered net returns of ₹ 11503/ha and BCR of 1.85. Better weed control by the herbicides resulted in increased grain yield and reduced cost of weeding were reason behind higher net profit. Similar magnitude of higher profit due to PE and PoE herbicides has been reported by Komal *et al.* (2015) and Kalhapure *et al.* (2013). This was followed by application of imazethapyr at 50 g/ha on 15 DAS, which gave ₹ 9250/ha. Manual weeding twice at 15 and 30 DAS gave lesser net returns of ₹ 5260/ha mainly because of higher cost of manual weeding. Control plot gave negative net returns in both the seasons because of higher weed competition led to lesser grain yield.

Thus, it was concluded that application of PE herbicide pendimethalin 1.0 kg/ha on 3 DAS followed by PoE herbicide imazethapyr 50 g/ha on 30 DAS controlled the *Trianthema portulacastrum* effectively and produced higher productivity and profitability of greengram in irrigated condition.

REFERENCES

Chhodavadia SK. 2014. Efficacy of pre- and post- emergence herbicide for integrated weed management in summer green gram (*Vigna radiata L*. Wilczek). In: *2nd International Conference on Agriculture and Horticultural Sciences*. February 03-05-2014. Hyderabad, India.

Gomez KA and Gomez AA. 1984. *Statistical Procedure for Agricultural Research*. John Wiley and Sons, New York.

Kalhapure AH, Shete BT and Bodake PS. 2013. Integration of chemical and cultural methods for weed management in groundnut. *Indian Journal of Weed Science* **45**(2): 116–119.

Kaur S, Kaur T and Bhullar MS. 2016. Imidazolinone herbicides for weed control in greengram. *Indian Journal of Weed Science* **48**: 37–39.

Komal, S.P. Singh and R.S. Yadav. Effect of weed management on growth, yield and nutrient uptake of green gram. *Indian Journal of Weed Science* **47**(2): 206–210.

Muthuram T Krishnan R and Baradhan G. 2018. Productivity enhancement of irrigated greengram (*vigna Vigna radiata* l.) through integrated weed management. *Plant Archives* **8**(1): 101–105.

Patel VM Patel VS and Thanki JD. 2011. Effect of irrigation levels and weed management practices on weed growth and yield of summer blackgram (*Phaseolus mungo* (L.) Hepper) under South Gujarat condition. *Green Farming* **2**(2): 182–184.

Ramesh T and Rathika S. 2016. Management of emerged weeds in irrigated blackgram (*Vigna mungo L.*) through greengram herbicides. *Legume Research* **39**(2): 289–292

Saeed M Khan Bahadar Marwat Gul Hassan Azim Khan and Ijaz Ahmad Khan. 2010. Interference of horse purslane (*T. portulacastrum* L.) with maize (*Zea mays* L.) at different densities. *Pakistan Journal Botany* **42**(1): 173–179.

Sangwan M, Samunder Singh and Satyavan. 2016. Efficacy of imazethapyr applied alone and mixed with pendimethalin or imazamox in cluster bean (Cyamopsis tetragonoloba) and their residual effect on mustard (*Brassica juncea*) in two texturally different soils. *Indian Journal of Agricultural Sciences* **86**(2): 256–66

Senthil A Chinnusamy C Kumar G and Prabhakaran NK. 2009. Identification of threshold level of horsepurslane (*T. portulacastrum*) in irrigated cowpea (*Vigna unguiculata*). *Indian Journal of Crop Science* **4**(1&2): 141–143.

Indian Journal of Weed Science **52**(3): 290–291, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Indian Journal of Weed Science

Integrated weed management in blackgram

R.P.S. Shaktawat

Krishi Vigyan Kendra, Agar Malwa, Madhya Pradesh 465 441, India

Email: rpssbkn@yahoo.co.in

Article information

DOI: 10.5958/0974-8164.2020.00057.X

Type of article: Research note

Received : 17 April 2020

Revised : 6 September 2020

Accepted : 9 September 2020

Key words

Blackgram, Economics, Weed

ABSTRACT

An on farm testing (OFT) was conducted in the farmer's field of Daloda Rail village, Mandsaur district, Madhya Pradesh in kharif season of 2014, 2015 and 2016 to assess the effect of integrated weed management treatments on weed management and yield of blackgram (*Vigna mungo* L.). Application of imazethapyr 75 g/ha at 18 days after seeding (DAS) and hand weeding at 40 DAS gave 36.91% mean higher blackgram grain yield as compare to farmer's practice (0.88 t/ha). Further, this treatment also resulted in significantly higher blackgram plant height, pods/plant, net return and B:C ratio as compared to all other tested treatments and significantly reduced the weed density and biomass as recorded at 45 DAS as compared to all other treatments tested.

Blackgram (*Vigna mungo* L.) is one of the important pulse crops of India. It is cultivated mostly on the marginal lands, under rainfed situations. Majority of farmers in rainfed regions are unaware about new varieties and improved package of practice of cultivation. In India, blackgram are grown in 3.75 million ha area with a total production of 2.49 million tonnes and productivity of 664 kg/ha out of which 1.82 million ha area with a production of 1.35 million tonnes and productivity of 739 kg/ha is under Madhya Pradesh with first rank (Anonymous 2018). The productivity of blackgram can be increased by adopting improved package of practices in a systematic manner with high yielding varieties of blackgram. Among different constraints to attain higher productivity and production of blackgram, weeds pose a serious problem during *Kharif* season and weeds cause losses up to 50-60% (Das *et al.* 2014). Weeds can be managed mechanically by one hand weeding at 20 DAS followed by another hand weeding at 40 DAS (Bhowmick *et al.* 2015), but hand weeding is labour intensive. Further, continuous rainfall during the initial growth period of crop makes the manual weeding impracticable and Therefore, chemical herbicide becomes cost effective. Thus, it is a major challenge to maximize the productivity of blackgram during *Kharif* season. Under these situations, integrated weed management practice involving both chemical and agronomic practice is an effective tool to increase the productivity of crop (Kavad *et al.* 2016). Keeping all these in mind, an on-farm trial (OFT) was conducted to assess the efficacy of integrating post-emergence herbicides with other weed management practices for effectively control weeds in blackgram in Mandsaur district of Madhya Pradesh.

An on-farm testing was conducted using randomized black design technique during three consecutive *Kharif* seasons of 2014, 2015 and 2016 in the adopted village Daloda Rail by Krishi Vigyan Kendra, Mandsaur. This OFT was conducted at 10 farmer's fields with '*JU 86*' variety of blackgram during all the years. Each treatment was laid out in 2000 sqm area. The treatments were farmer practice (hand weeding at 15, 30 and 45 days after seeding [DAS]), imazethapyr 75 g/ha at 18 DAS and imazethapyr 75 g/ha at 18 DAS and hand weeding at 40 DAS. The herbicides were applied manually by knapsack sprayer fitted with flat-fan nozzle using spray volume of 500 L/ha. Blackgram was sown in the second week of July and harvested in first week of October. Recommended package of practices was followed to raise the crop. The observation on weed biomass and density were recorded at 45 DAS using quadrate (0.5 x 0.5 m), placed randomly at two places in each plot. Economics of weed management treatments were worked out by using current market price of inputs and blackgram. All the data recorded were analyzed statistically as per the methods suggested by Gomez and Gomez (1984).

Effect on weeds

The predominant weeds noticed in blackgram field were *Cyperus rotundus*, *Cynodon dactylon* Pers., *Echinochloa colona*, *Commelina benghalensis*, *Euphorbia hirta* and *Parthenium hysterophorus*. Imazethapyr 75 g/ha at 18 DAS and hand weeding at 40 DAS was found to be significantly superior to all

Table 1. Effect of weed management treatments on blackgram plant height and associated weeds density and biomass

Treatment	Plant height (cm)				Weeds density/m^2				Weeds biomass (g/m^2)			
	2014	2015	2016	Mean	2014	2015	2016	Mean	2014	2015	2016	Mean
Farmer's practice (HW at 15, 30 and 45 DAS)	51.0	37.0	41.0	43.0	15.0	20.4	18.0	17.80	13.80	17.88	15.46	15.71
Imazethapyr 75 g/ha at 18 DAS	60.7	41.8	47.0	49.8	7.0	7.2	6.2	6.80	2.10	1.91	3.78	2.59
Imazethapyr 75 g/ha at 18 DAS and HW at 40 DAS	64.1	49.5	52.5	55.4	2.0	5.1	4.0	3.70	1.57	1.33	2.91	1.94
LSD (p=0.05)	4.67	8.76	6.70	3.52	0.66	0.54	0.88	0.36	0.501	0.541	0.414	0.248

Table 2. Effect of weed management treatments on number of pods, grain and straw yield of blackgram

Treatment	No. of pods/plants				Grain yield (kg/ha)				Straw yield (t/ha)			
	2014	2015	2016	Mean	2014	2015	2016	Mean	2014	2015	2016	Mean
Farmer's practice (HW at 15, 30 and 45 DAS)	24.4	22.4	22.8	23.2	667	520	820	669	1.51	1.17	1.84	1.51
Imazethapyr 75 g/ha at 18 DAS	30.4	26.4	28.0	28.3	712	630	1060	801	1.63	1.44	2.43	1.83
Imazethapyr 75 g/ha at 18 DAS and HW at 40 DAS	35.2	27.2	29.2	30.5	794	720	1130	881	1.84	1.68	2.63	2.05
LSD (p=0.05)	1.38	0.77	1.17	0.57	27	40	42	19	0.06	0.09	0.09	0.04

Table 3. Effect of weed management treatments on gross return, net return and B:C ratio of blackgram

Treatment	Gross return (x10^3 ₹/ha)				Net return (x10^3 ₹/ha)				B:C ratio			
	2014	2015	2016	Mean	2014	2015	2016	Mean	2014	2015	2016	Mean
Farmer's practice (HW at 15, 30 and 45 DAS)	30.01	23.40	57.40	36.94	13.51	6.90	40.90	20.44	1.82	1.42	3.48	2.24
Imazethapyr 75 g/ha at 18 DAS	32.04	28.35	74.20	44.86	14.54	10.85	56.70	27.36	1.83	1.62	4.24	2.56
Imazethapyr 75 g/ha at 18 DAS and HW at 40 DAS	35.73	32.40	79.10	49.08	16.93	13.60	60.30	30.28	1.90	1.72	4.21	2.61
LSD (p=0.05)	1.23	1.81	2.94	1.07	1.23	1.81	2.94	1.07	0.07	0.10	0.17	0.06

other treatments including farmers practice in reducing weed density and biomass. These results were in close conformity with those reported by Bhowmick *et al.* (2015) Chhodavadia *et al.* (2013) Das *et al.* (2014) Ramesh and Rathika (2016).

Effect on blackgram

Application of imazethapyr 75 g/ha at 18 DAS and hand weeding at 40 DAS found significantly superior over farmers' practice and imazethapyr 75 g/ ha at 18 DAS. All weed control treatments significantly increased the plant height of blackgram as compared to farmer practice (**Table 1**). The maximum plant height, pods per plant and yield of blackgram (**Table 2**) observed with imazethapyr 75 g/ ha at 18 DAS and hand weeding at 40 DAS (55.4 cm) and it was followed by treatment imazethapyr 75 g/ha at 18 DAS, which might be due to lesser weed competition as a result of better weed control by the herbicide combined with hand weeding as earlier reported by Kavad *et al.* (2016), Ramesh and Rathika (2016).

Economics

On the basis of pooled data (**Table 3**), imazethapyr 75 g/ha at 18 DAS and hand weeding at 40 DAS treatment fetched the significantly highest net return and B:C ratio (₹ 30277/ha and 2.61) followed by imazethapyr 75 g/ha at 18 DAS treatment. The lowest B:C ratio was observed under farmers' practice as compared to all other treatments tested. The lowest investment under imazethapyr 75 g/ha at 18 DAS and hand weeding at 40 DAS treatment coupled with good economic return of grain yield might be reason for highest net returns and B:C ratio. Similar findings were also reported by Chhodavadia *et al.* (2013) Ramesh and Rathika (2016).

Conclusion

On the basis of three years data, it was concluded that application of imazethapyr 75 g/ha at 18 days after seeding (DAS) and hand weeding at 40 DAS gave significantly higher blackgram grain yield as compare to farmer's practice and reduced the weed density and biomass as recorded at 45 DAS as compared to all other treatments tested.

REFERENCES

Bhowmick MK, Duary B and Biswas PK. 2015. Integrated weed management in blackgram. *Indian Journal of Weed Science* **47**(1):34–37.

Anonymous. 2018. *Agricultural Statistics at a Glance 2018*. Ministry of Agriculture and Farmer welfare, GOI, New Delhi.

Chhodavadia SK, Mathukiya RK and Dobariya VK. 2013. Pre and Post emergence herbicide for integrated weed management in summer greengram. *Indian Journal of Weed Science* **45**(2):137–139.

Das R, Patra BC, Mandal MK and Pathak A. 2014. Integrated weed management in blackgram (*Vigna mungo* L.) and its effect on soil micro-flora under sandy loam soil of West Bengal. *The Bioscan* **9**(4): 1593–1596.

Gomez KA and Gomez AA. 1984. *Statistical Procedures for Agricultural Research*. John Willey and Sons, New York.

Kavad NB, Patel CK, Patel AR and Thumber BR. 2016. Integrated weed management in blackgram. *Indian Journal of Weed Science* **48**(2): 222–224.

Ramesh T and Rathika S. 2016. Management of emerged weeds in irrigated blackgram (*Vigna mungo* L.) through post-emergence herbicides. *Legume Research* **39**(2): 289–292.

Indian Journal of Weed Science **52**(3): 292–295, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Effect of plant extracts and rice straw mulch on weed growth and yield of groundnut

N. Sai Geethika, D. Subramanyam*, S. Tirumala Reddy and V. Umamahesh
Sri Venkateswara Agricultural College, Tirupati, Andhra Pradesh 517 502, India
**Email: subbuagro37@gmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00058.1

Type of article: Research note

Received : 17 April 2020
Revised : 14 July 2020
Accepted : 16 July 2020

Key words
Plant extracts

Weed dry weight

Weed control efficiency

Yield

ABSTRACT

Sorghum (*NJ-2647*), sunflower (*NDSH-1012*) and rice (*NLR-34449*) were grown up to physiological maturity and harvested for preparing plant extracts during *Kharif* 2017 at Sri Venkateswara Agricultural College, Tirupati, Andhra Pradesh. Plant parts of *Parthenium hysterophorus*, *Lantana camera* and *Cyperus rotundus* were collected from the non-cropped area at flowering. The chopped material of above plants were soaked separately in distilled water for 24 hours at room temperature of 21^{0}C at a ratio of 1:10 (w/v) and the same was filtered through 10 and 60 mesh sieve separately. A field experiment was conducted during *Rabi* 2017-18 in a randomized block design with 10 treatments to evaluate the performance of different plant extracts each applied at 15 L/ha at 15 and 30 DAS and rice straw mulch 5 t/ha for weed management in groundnut. The application of rice straw mulch 5 t/ha was found to be the best followed by sunflower extract spray for obtaining higher pod yield and maximum net returns, besides effective control of weeds in groundnut in view of sustainability and reduce the load of herbicides in the soil, however pre-emergence application of pendimethalin 1.0 kg/ha + HW at 30 DAS produced higher pod yield and net returns.

Groundnut (*Arachis hypogaea* L.) is known as poor man's cashew nut and an important oil seed crop grown around the world as well as in India. Among the several factors limiting the productivity of groundnut, weeds are considered to be one of the major yield limiting factors due to its short stature and slow initial growth. Heavy weed infestation in groundnut reduces the pod yield as high as 24 to 70% and first three to four weeks of crop growth period was critical for weed control in groundnut grown on sandy loam soils of Varanasi, Uttar Pradesh (Singh *et al.* 2014). Generally, weeds are controlled through hand weeding in groundnut, but it is expensive and laborious. Herbicide application is expensive and poses detrimental effect on the environment. In recent years, research attention is now being focused on reducing the dependence upon synthetic herbicides and finding alternative strategies for weed management in sustainable and organic agricultural systems.

Allelopathy offers potential for bio-rational weed control through production and release of allelochemicals from leaves, stem, root, flower and seeds of living or decomposing plant materials (Hien *et al.* 2015). Number of secondary metabolites / allelomones is being screened for herbicidal properties from different plants with considerable crop selectivity, which can be used directly in the form of aqueous plant extracts and indirectly gives clues for developing analogs of herbicides. Kandhro *et al.* (2015) observed that the application of allelopathic plant extract of sunflower 25 L/ha twice at 15 and 30 DAS resulted in reduced weed density in cotton at clay loam soils of Peshwar, Pakistan. There is a scope for use of certain weed water extracts for controlling weeds due to presence allelopathic chemicals. Foliar application of allelopathic water extracts of *P. hysterophorus* 24 L/ha in combination with reduced doses of bromoxynil 150 g/ha significantly reduced the weed density in wheat (Baloach *et al.* 2012). In this context, the present investigation was planned to study the performance of different organic weed management strategies by including plant water extracts and rice straw mulch to control mixed weed flora in groundnut on sandy loam soils.

Sorghum (*NJ-2647*), sunflower (*NDSH-1012*) and rice (*NLR-34449*) were sown in wet land farm during *Kharif 2017* in an area of 20 m^2 each by adopting all the package of practices of Acharya N.G.

Ranga Agricultural University. These crops were harvested at physiological maturity and shade dried for 10 days and stored. Plant parts of *Parthenium hysterophorus* L. and *Lantana camara* L. were collected at flowering stage and dried under shade conditions. Tubers of *Cyperus rotundus* L. were collected from the soil, cleaned and dried under shade. The dried material of entire plant parts above the ground and tubers of purple nutsegde were chopped with power operated chaff cutter into 2 cm pieces, separately. The chopped plant material was soaked in distilled water for 24 hours at room temperature of 21^0C at a ratio of 1:10 (w/v) and the same was filtered through 10 and 60 mesh sieve separately. These plant extracts were boiled at 100^0 C to concentrate solution up to 20 times for easy handling and application.

A field experiment was conducted at wetland farm, Sri Venkateswara Agricultural College, Tirupati campus of Acharya N.G. Ranga Agricultural University, Andhra Pradesh, to study the performance of different plant extracts and rice straw mulch for weed management in groundnut during *Rabi* 2017-18. The soil was sandy loam in texture, neutral in soil reaction (7.70), electrical conductivity (0.65 dS/m), low in organic carbon (0.23%) and available nitrogen (128 kg/ha), medium in available phosphorus (12 kg/ha) and available potassium (225 kg/ha). The groundnut variety *'TCGS 1043' (Dharani)* was sown with a spacing of 22.5 x 10 cm on 22 December, 2017. The experiment was laid out in randomized complete block design and replicated thrice with ten weed management practices, *viz*. plant extracts of sorghum, sunflower, rice straw, *Parthenium, Lantana* and purple nutsedge each applied at 15 L/ha at 15 and 30 DAS, rice straw mulch 5 t/ha, pre-emergence application of pendimethalin 1.0 kg/ha supplemented with HW at 30 DAS, post-emergence application of imazethapyr 75 g/ha and unweeded check. The required quantities of filtered concentrated plant extracts, imazethapyr and pendimethalin were applied as per the treatments by using spray fluid of 500 L/ha with the help of knapsack sprayer fitted with flat fan nozzle. Rice straw mulch was applied carefully in between the rows at 5 DAS. The crop was supplied with recommended dose of fertilizer *i.e.* 30 kg N, 40 kg P and 50 kg K/ha through urea, single super phosphate and muriate of potash, respectively. The category wise weed density and weed dry weight was estimated at harvest. Weed control efficiency and weed index was calculated as per the method suggested by Mani *et al.* (1973) and Gill and Kumar (1969), respectively. The data on weed density and dry weight was subjected to square-foot transformation before statistical analysis. The yield attributing parameters like number of filled pods/plant, pod yield, haulm yield and test weight were recorded at harvest.

Weed growth

The predominant weed flora observed in groundnut field were *Cyperus rotundus* (45%), *Digitaria sanguinalis* (15%), *Borreria hispida* (7%), *Digera arvensis* (6%), *Boerhavia erecta*(5%), *Cleome viscosa* (3%), *Dactyloctenium aegyptium* (4%), *Trichodesma indicum* (4%), *Phyllanthus niruri* (4%) and other weeds (7%) in unweeded check plots. All the weed management practices significantly influenced the density and dry weight of grasses, sedges, broad-leaved weeds and weed control efficiency (**Table 1**). The lowest density and dry weight of grasses were recorded with pre-emergence application of pendimethalin 1.0 kg/ha+ HW at 30 DAS than rest of the treatments. Among the organic weed management practices, rice straw

Table 1. Effect of different plant extracts on weed density, weed dry weight and weed control efficiency in groundnut during *Rabi* 2017-18

Weed management practice	Weed density (no./m²)				Weed dry weight (g/m²)				WCE (%)
	Grasses	Sedges	BLWs	Total	Grasses	Sedges	BLWs	Total	
Sorghum extract 15 L/ha (15 and 30 DAS)	5.57(30)	5.94(34)	5.69(31)	9.83(95)	4.76(22)	5.07(25)	4.87(20)	8.22(67)	57.4
Sunflower extract 15 L/ha (15 and 30 DAS)	4.55(20)	5.74(32)	5.13(25)	8.80(77)	4.63(20)	4.86(23)	4.51(19)	7.92(62)	61.6
Rice straw extract 15 L/ha (15 and 30 DAS)	6.03(35)	6.76(45)	5.92(34)	10.70(114)	5.16(26)	5.32(27)	4.99(24)	8.79(77)	52.6
Parthenium extract 15 L/ha (15 and 30 DAS)	6.43(40)	7.09(49)	6.40(40)	11.43(129)	5.32(27)	5.81(33)	5.23(26)	9.33(86)	46.6
Lantana extract 15 L/ha (15 and 30 DAS)	5.69(31)	6.51(41)	5.80(33)	10.31(105)	4.88(23)	5.27(27)	4.60(23)	8.38(73)	57.0
Purple nutsedge extract 15 L/ha (15 and 30 DAS)	6.19(37)	7.07(49)	6.25(38)	11.20(124)	5.41(28)	5.61(30)	5.14(25)	9.20(83)	48.1
Rice straw mulch 5 t/ha (5 DAS)	4.51(19)	4.93(23)	4.54(20)	7.93(62)	3.41(11)	4.50(19)	3.07(8)	6.23(38)	76.3
Pendimethalin 1.0 kg/ha + HWs (1 and 30 DAS)	3.21(9)	4.65(21)	3.27(10)	6.34(40)	2.64(6)	4.06(15)	2.55(5)	5.23(26)	83.4
Imazethapyr 75 g/ha (20 DAS)	4.12(16)	4.65(21)	3.65(12)	7.04(49)	3.22(9)	4.85(22)	3.38(10)	6.55(41)	73.8
Unweeded check	9.26(85)	11.47(131)	9.33(86)	17.37(301)	6.07(36)	8.38(69)	7.61(57)	12.75(162)	-
LSD (p=0.05)	0.12	0.22	0.16	0.85	0.38	0.42	0.34	0.31	

Figures in the parentheses are the original values and subjected to square root transformation; BLWs: Broad-leaved weeds mulch 5 t/ha recorded significantly lesser density of grasses, which was at par with sunflower extract spray 15 L/ha applied at 15 and 30 DAS, but the former treatment recorded significantly lesser dry weight of grassy weeds than later. The lowest density of sedges was recorded with rice straw mulch 5 t/ha, which was at par with pendimethalin 1.0 kg/ha + HW at 30 DAS. Among the plant extracts, sunflower extract recorded significantly lesser density and dry weight of sedges followed by sorghum extract spray each sprayed at 15 L/ha at 15 and 30 DAS. Iqbal *et al.* (2007) also stated that sunflower extract at 12 and 15 l/ha alone or mixed with reduced rate of glyphosate decreased the density of *C. rotundus* by 59 to 99% in cotton. Significantly lesser density and dry weight of broad-leaved weeds were recorded with pre-emergence application of pendimethalin 1.0 kg/ha + HW at 30 DAS, however it was comparable with rice straw mulch 5 t/ha. Among the plant extracts, sunflower extract spray 15 L/ha recorded significantly lesser density of broad-leaved weeds followed by sorghum extract. Among the plant extracts, sunflower extract recorded significantly lower density and dry weight of total weeds, which was in parity with sorghum extract. The highest density and dry weight of total weeds was noticed with parthenium extract spray followed by purple nutsedge extract spray, among the plant extracts.

The highest weed control efficiency was computed with pre-emergence application of pendimethalin 1.0 kg/ha + HW at 30 DAS followed by post-emergence application of imazethapyr 75 g/ha. Among organic weed management practices, rice straw mulch 5 t/ha registered maximum weed control efficiency followed by sunflower extract 15 L/ha applied twice at 15 and 30 DAS. Rice straw mulch might have increased the albedo and decreased the solar energy flux to the soil, which in turn reduce the germination and dry weight of weeds (Lalitha *et al.* 2010). Foliar application of aqueous extract of sorghum and sunflower each 15 L/ha at 20 DAS reduced the density of *Trianthema portulacastrum* and C. *rotundus* by 45.8 and 56.0%, respectively over control in maize grown on sandy clay loam soils. The lowest weed control efficiency was calculated with parthenium extract spray followed by purple nutsedge extract spray.

Yield attributes and yield

Among the weed management practices, the highest values of yield components, *viz.* number of filled pods/plant, hundred pod weight and hundred kernel weight were recorded with pre-emergence application of pendimethalin 1.0 kg/ha + HW at 30 DAS followed by post-emergence application of imazethapyr 75 g/ha (**Table 2**). Among the organic weed management practices, the highest values of above yield parameters were registered with rice straw mulch 5 t/ha followed by sunflower extract 15 L/ha applied twice at 15 and 30 DAS. This might be due to maintenance of better source-sink relations owing to adequate availability of growth resources as a result of less weed competition. The positive effect of rice straw mulch on growth and yield attributes in soybean was also reported by Eid *et al.* (2013) with rice straw 15 t/ha. Parthenium extract 15 L/ha applied twice recorded significantly lesser values of above yield components of groundnut which were at par with purple nutsedge extract spray, among the plant extracts.

All the chemical weed management practices recorded significantly higher pod and haulm yield than organic weed management practices due to maintenance of weed free environment at early stages of crop growth which might have increased yield components. Among the organic weed management practices, rice straw mulch 5 t/ha produced significantly higher pod yield than rest of the

Table 2. Effect of different plant extracts on yield attributes, yield and economics of groundnut during *Rabi* 2017-18

Weed management practice	No. of filled pods/plant	100- pod weight (g)	100- kernel weight (g)	Pod yield (t/ha)	Haulm yield (t/ha)	Harvest Index (%)	Weed index (%)	Net returns ($x10^3$ ₹/ha)	B:C ratio
Sorghum extract 15 L/ha (15 and 30 DAS)	11.4	129.1	53.87	1.85	2.49	42.60	33.40	39.69	2.08
Sunflower extract 15 L/ha (15 and 30 DAS)	11.7	138.3	54.63	1.90	2.51	43.12	31.34	43.33	2.23
Rice straw extract 15 L/ha (15 and 30 DAS)	10.7	123.9	52.57	1.61	2.46	39.60	41.78	30.37	1.83
Parthenium extract 15 L/ha (15 and 30 DAS)	10.0	118.9	46.87	1.39	2.38	36.95	49.68	21.21	1.57
Lantana extract 15 L/ha (15 and 30 DAS)	10.9	126.5	52.67	1.72	2.48	40.85	38.09	34.17	1.92
Purple nutsedge extract 15 L/ha (15 and 30 DAS)	10.3	122.6	51.53	1.42	2.39	37.29	48.82	21.76	1.58
Rice straw mulch 5 t/ha (5 DAS)	12.5	143.9	55.87	2.09	2.58	44.48	24.42	44.61	2.15
Pendimethalin 1.0 kg/ha + HW (1 and 30 DAS)	13.3	146.1	59.37	2.77	2.65	51.10	-	71.86	3.04
Imazethapyr 75 g/ha (20 DAS)	11.8	144.0	56.87	2.55	2.60	49.53	7.88	67.41	2.85
Unweeded check	8.9	108.5	42.20	1.32	2.17	37.68	52.51	19.65	1.56
LSD (p=0.05)	0.49	5.60	2.25	0.16	0.11	1.73	-	3.96	0.12

treatments (**Table 2**). The increased pod yield was possibly due to better weed control which resulted in better growth parameters and in turn increased the yield attributes and higher pod yield. The next best organic weed management practice in recording higher pod yield with sunflower extract spray, which was at par with sorghum extract spray each applied at 15 L/ha applied at 15 and 30 DAS. Naeem *et al.* (2016) also reported that application of sorghum and sunflower extracts 15 L/ha at 20 DAS in maize increased the grain yield by 50.4%.The highest harvest index (51.1%) in groundnut was calculated with pre-emergence application of pendimethalin 1.0 kg/ha + HW at 30 DAS, which was comparable with post-emergence application of imazethapyr 75 g/ha. Among the organic weed management practices, rice straw mulch 5 t/ha recorded significantly higher harvest index (44.48 %), which was comparable with sunflower extract spray. The increased harvest index with increased weed control efficiency might be due to increased availability of growth resources and partitioning ability of photosynthates, which lead to increased pod yield. Similar results were also reported by Marwat *et al.* (2008).The lowest weed index was estimated with rice straw mulch 5 t/ha followed by sunflower extract spray 15 L/ha as these weed management practices recorded significantly lesser density and dry weight of weeds which in turn increased the pod yield. Rahaman and Mukherjee (2012) also recorded lower weed index with application of rice straw mulch 8 t/ha in jute. Application of rice straw mulch 5 t/ha recorded significantly higher net returns and benefit-cost ratio followed by sunflower and sorghum extracts each applied at 15 L/ha in descending order, among the organic weed management practices. The experimental results indicated clearly that the application of rice straw mulch 5 t/ha and sunflower extract spray 15 L/ha twice at 15 and 30 DAS were found to be the best for broad-spectrum weed control and obtaining higher pod yield including maximum net returns in groundnut in view of sustainability and reduce the load of herbicides in the soil.

REFERENCES

Baloch MS, Noor K, Khan EA, Khan MA, Awan IU, Sadiq M and Aslam M. 2012. Allelopathic effect of congress grass on weeds and yield of wheat. *Pakistan Journal of Weed Science Research* **18**(3): 307–318.

Eid AR, Bakry BA and Taha MA. 2013. Effect of pulse drip irrigation and mulching systems on yield, quality traits and irrigation water use efficiency of soybean under sandy soil conditions. *Agricultural Sciences* **4**(5): 249–261.

Gill GS and Kumar K. 1969. "Weed Index" a new method for reporting weed control traits. *Indian Journal of Agronomy* **14**: 96–78.

Hien LT, Park SH, Park YJ, Won OJ, Hwang JB, Park SU and Park KW. 2015. *Research on Crops* **16**(4): 657–662.

Iqbal J, Cheema ZA and An M. 2007. Intercropping of field crops in cotton for management of purple nutsedge (*Cyperus rotundus L.*). *Plant and Soil* **300**: 163–171.

Kandhro MN, Memon HR, Ansari MA and Shah MA. 2015. Effect of allelopathic water extract of sorghum and sunflower on weed mortality and cotton yield. *Sarhad Journal of Agriculture* **31**(3): 165.

Lalitha M, Thilagam VK, Balakrishnan N and Monsour M. 2010.Effect of plastic mulch on soil properties and crop growth–A review. *Agricultural Reviews* **31**: 145–149.

Mani VS, Malla ML, Gautam KC and Bhagavandas. 1973. Weed killing chemicals in potato cultivation. *Indian Farming* **23**: 17–18.

Marwat KB, Khan MA, Anwar N and Amin A. 2008. *Parthenium hysterophorus*, a potential source of bioherbicide. *Pakistan Journal of Botany* **40**(5): 1933–1942.

Naeem M, Mahmood A, Ihsan MZ, DaurI , Hussain S, Aslam Zand Zamanan SA. 2016. *Trianthema portulacastrum* and *Cyperus rotundus* interference in maize and application of allelopathic crop extracts for their effective management. *Planta Daninha* **34**(2): 209–218.

Rahaman S and Mukherjee PK. 2012. Comparative evaluation between rice straw mulching and herbicides for weed control in jute (*Corchorus olitorius* L.) under *tarai* agro–climatic region of West Bengal. *Journal of Crop and Weed* **8**(1): 184–186.

Singh R, Chaurasia S, Gupta AV and Soni P. 2014. Studies on effect of *Parthenium hysterophorus* plants extract on germination and growth in certain pulses. *Journal of Agricultural Science* **4**(4): 235–239.

Indian Journal of Weed Science **52**(3): 296–299, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Integrated weed management impact on soil biological indicators in cowpea

J.K. Sinchana and Sheeja K Raj*

College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapuram, Kerala 695 522, India

**Email: sheejakraj70@gmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00059.3

Type of article: Research note

Received : 6 July 2020
Revised : 17 September 2020
Accepted : 22 September 2020

Key words

Dehydrogenase enzyme activity

Diclosulam

Enzyme activity

Imazethapyr

Nodules

ABSTRACT

Impact of integrated weed management practices involving stale seedbed, mulching with dried banana leaves, herbicides, *viz*. pre-emergence (PE) diclosulam, post-emergence (PoE) quizalofop-p-ethyl and imazethapyr and manual weeding on nodulation in bush cowpea and enzyme activity in soil was studied. Stale seedbed recorded significantly higher number of total nodules per plant. Dehydrogenase enzyme activity was also higher in stale seedbed however, urease enzyme activity did not have any significant effect at 15 and 30 DAS. Treatments with imazethapyr recorded lesser number of total nodules than treatments with diclosulam and quizalofop-p-ethyl. Among the herbicide treatments at 15 DAS, PE diclosulam registered significantly higher urease and dehydrogenase enzyme activity than weedy check and comparable activity with hand weeding treatment. Post-emergence imazethapyr showed a reduction in dehydrogenase and urease enzyme activity at 30 DAS compared to 15 DAS. However, PoE quizalofop-p-ethyl registered higher dehydrogenase and urease enzyme activity at 30 DAS compared to 15 DAS and values were comparable or higher than that of hand weeding treatment.

Integrated weed management involving chemical and non-chemical method is the viable solution for weed control in bush type vegetable cowpea. Soil enzyme activity are the indicators of soil health and are considered as biological fingerprints of management practices. If herbicides were applied to the soil, major portion of the applied herbicides accumulated in the top layer (0-15 cm) (Latha and Gopal 2010). Ramesh *et al.* (2000) reported that the herbicide, imazethapyr did not have any negative impact on urease activity in soil. However, Majumdar *et al.* (2010) revealed that quizalofop-p-ethyl inhibits the soil urease enzyme activity. Yang *et al.* (2003) observed that mulched plot recorded the highest enzyme activity. Diclosulam as pre plant surface spray 17.5 g/ha did not hamper nodulation in green gram and can be considered as a safe dose (Deepa *et al*. 2017). Pre-emergence (PE) pendimethalin 1.0 kg/ha *fb* quizalofop-p-ethyl and imazethapyr 50 g/ha recorded higher number of nodules per plant in green gram (Muthuram *et al*. 2018). Herbicides should effectively control the weeds but also safe to the crop and environment. Hence, present study was undertaken to evaluate the influence of different weed management practices on weed density, green pod yield and nodulation in bush type vegetable cowpea and soil enzyme activity.

Experiment was carried out at Coconut Research Station, Balaramapuram, Thiruvananthapuram, Kerala during *Kharif* 2019. During the cropping season 919 mm of rainfall was received and the average and minimum temperature was recorded 32.06 and 17.79^{0}C, respectively. Soil texture of the experimental site was red loam, acidic in reaction with high organic carbon content (0.79%), low N (206.3 kg/ha), high P (39.17 kg/ha) and medium K (137.28 kg/ha). The experiment was carried out in randomized block design with seedbed preparation and weed management practices as two factors in three replications. Seedbed preparation comprised of stale seedbed (SSB) and normal seedbed (no stale). Weed management practices comprised of dried banana leaf mulch10 t/ha, dried banana leaf mulch 10 t/ha *fb* imazethapyr 50 g/ha at 25 DAS, dried banana leaf mulch 10 t/ha *fb* quizalofop-p-ethyl 50 g/ha at 25 DAS, imazethapyr 50 g/ha at 15 DAS, diclosulam 12.5 g/ha (pre-emergence) *fb* quizalofop-p-ethyl 50 g/ha at 25 DAS, diclosulam 12.5 g/ha (pre-emergence) *fb* hand weeding at 25 DAS, hand weeding at 20 and 40 DAS and weedy check. Diclosulam was applied on the day of sowing the cowpea seeds, imazethapyr and quizalopfop-p-ethyl were applied as per the treatment schedule. The spray fluid adopted for the experiment was 500 L/ha. Test crop used for the study was '*Bhagyalakshmy*', a short duration variety (80 days). Farm yard manure (FYM) 20 t/ha was applied basally and NPK dose of 20: 30: 10 kg/ha was adopted. Nitrogen was applied in two splits (half as basal and half at 20 DAS), entire P and K as basal. To correct the acidity, 250 kg/ha of lime was applied and incorporated into the soil at the time of final ploughing.

Total weed density at 45 DAS was determined by placing a quadrate of size 0.5 x 0.5 m at two spots in each treatment and average was worked out and expressed as no./m^2. Green pod yield was expressed in t/ha. Total number of nodules per plant was recorded at fifty per cent flowering stage. Composite samples were collected at 15 and 30 DAS for the analysis of soil dehydrogenase and urease enzyme activity. The methodology suggested by Casida *et al.* (1964) was employed for the determination of dehydrogenase activity and method suggested by Watts and Crisp (1954) was adopted for the estimation of urease activity in soil. Analysis of variance was done for the statistical analysis of data.

Effect on dehydrogenase enzyme activity

Weed management treatments recorded higher dehydrogenase enzyme activity (**Table 1**) at 15 and 30 DAS compared to weedy check. At 15 DAS, treatments not receiving herbicides recorded higher dehydrogenase enzyme activity and the treatments receiving PE diclosulam 12.5 g/ha registered dehydrogenase activity comparable with hand weeding treatment. At 30 DAS, mulching with dried banana leaf 10 t/ha *fb* quizalofop-p-ethyl 50 g/ha at 25 DAS recorded the highest dehydrogenase enzyme activity which was significantly superior to other treatments. The treatments with dried banana leaf mulch recorded higher dehydrogenase enzyme activity compared to other treatments which might be due to higher substrate availability. Interaction effect was significant only at 30 DAS (**Table 1)**. At 30 DAS, the treatment stale seedbed + mulching with dried banana leaf 10 t/ha *fb* quizalofop-p-ethyl 50 g/ha at 25 DAS registered the highest dehydrogenase activity. The treatment, normal seedbed + no weeding (weedy check) recorded the lowest dehydrogenase enzyme activity at 15 and 30 DAS. This might be owing to lesser substrate availability as a result of season long weed infestation.

Effect on urease enzyme activity

Seedbed preparation had no significant impact on urease enzyme activity at 15 and 30 DAS. Application of PE diclosulam 12.5 g/ha *fb* hand weeding at 25 DAS recorded the highest urease enzyme activity which was significantly higher compared to other treatments (**Table 1**). However, at 30 DAS, PE diclosulam 12.5 g/ha *fb* quizalofop-p-ethyl 50 g/ha at 25 DAS recorded the highest urease enzyme activity which was at par with PE diclosulam 12.5 g/ha *fb* hand weeding at 25 DAS and mulching with dried banana leaf 10 t/ha *fb* quizalofop-p-ethyl 50 g/ha at 25 DAS. The differences in the urease enzyme activity observed among the treatments might be due to changes in soil pH and soil temperature. Yang *et al.* (2006) reported that urease activity in soil was based on the soil microbial community, pH and temperature. Interaction effect was significant only at 30 DAS and the treatment normal seedbed + PE diclosulam 12.5 g/ha *fb* hand weeding at 25 DAS recorded the highest urease enzyme activity, which was statistically at par with stale seedbed + PE diclosulam 12.5 g/ha *fb* hand weeding at 25 DAS, normal seedbed + mulching with dried banana leaf 10 t/ha *fb* quizalofop-p-ethyl 50 g/ha at 25 DAS and stale seedbed + hand weeding at 20 and 40 DAS.

Effect on total number of nodules per plant

Compared to normal seedbed (9.00), SSB registered higher number of total nodules per plant (12.0). There was, 26.32 per cent increase in total nodules per plant. Enhancement in photosynthesis and translocation of photosynthates to the root nodules resulted in the development of a greater number of root nodules. Chatta *et al.* (2007) observed that poor plant growth adversely affected the nodule formation. Tehria *et al.* (2015) reported that in pea, nodule count was found to be the highest in SSB compared to herbicide treatment.

Weed management treatments recorded higher number of total nodules per plant, however, variations were observed among the treatments due to the specific soil condition prevailed in each treatment. Effect of herbicide treatments on nodulation depends on the specific soil condition, moisture content, soil organic matter and weather condition (Walley *et al.* 2006). Among the treatments, PE diclosulam 12.5 g/ha *fb* hand weeding at 25 DAS recorded significantly higher number of nodules (17.50) which was followed by PE diclosulam 12.5 g/ha *fb* quizalofop-p-ethyl 50 g/ha. It was also revealed from the data that treatments with imazethapyr, *viz.* PoE imazethapyr 50 g/ha at 15 DAS and mulching with dried banana leaf 10 t/ha *fb* imazethapyr 50 g/ha at 25 DAS recorded lesser number of nodules (8.00 and 9.17 no. per plant) than quizalofop-p-ethyl, *viz.* mulching with dried banana leaf 10 t/ha *fb* quizalofop-p-ethyl 50 g/ha at 25 DAS and PE diclosulam 12.5 g/

ha *fb* quizalofop-p-ethyl 50 g/ha at 25 DAS (12.83 and 13.17).

The treatment combination stale seedbed + PE application of diclosulam 12.5 g/ha *fb* hand weeding at 25 DAS recorded higher number of total nodules per plant (20.33) compared to other treatments (**Table 2**). This was owing to the fact that the beneficial effect of SSB coupled with diclosulam application resulted in the effective control of weeds enabled the crop to grow vigorously resulting in the effective transport of photosynthates from leaves to nodules.

Effect on total weed density and green pod yield of bush cowpea

Stale seedbed (SSB) recorded significantly lower total weed density at 45 DAS and higher green pod yield compared to no stale or normal seedbed **(Table 2)**. This might be due to the fact that removal of initial flushes of weeds prior to the sowing of cowpea seeds resulted in a competition free environment which might have contributed to higher green pod yield. Tehria *et al.* (2015) reported that SSB significantly brought down the density of weeds and higher yield in ground nut and Pea. Among the weed management practices, mulching with dried banana leaf 10 t/ha alone recorded the lowest total weed density and it was statistically at par with mulching with dried banana leaf 10 t/ha *fb* imazethapyr and quizalofop-p-ethyl 50 g/ha. The results also revealed that PoE application of imazethapyr 50 g/ha alone was not found effective in reducing the weed density in bush type vegetable cowpea. The result were in conformity with Kumavat *et al.* (2017) who observed that PoE application of imazethapyr alone was not effective in reducing the weed density in cluster bean. Result on green pod yield of bush type vegetable cowpea revealed that mulching with dried banana leaf 10 t/ha *fb* quizalofop-p-ethyl 50 g/ha at 25 DAS recorded the highest green pod yield. This might be due to the better control of weeds which reduced the crop weed competition, increased the availability and uptake of nutrients and resulted in higher green pod yield.

Interaction effect revealed that, stale seedbed + mulching with dried banana leaf 10 t/ha *fb* imazethapyr 50 g/ha at 25 DAS recorded the lowest total weed density which was statistically at par with mulching with dried banana leaf 10 t/ha alone and stale seedbed + mulching with dried banana leaf 10 t/ha *fb* quizalofop-p-ethyl 50 g/ha at 25 DAS. Though, the treatment stale seedbed + mulching with dried banana leaf 10 t/ha *fb* imazethapyr 50 g/ha at 25 DAS recorded the lowest weed density, the highest yield was recorded in seedbed + dried banana leaf mulching 10 t/ha *fb* quizalofop-p-ethyl 50 g/ha at 25 DAS. Under stale seedbed and normal seedbed, PoE imazethapyr 50 g/ha at 15 DAS recorded the highest density of weeds and the lowest green pod yield compared to other weed management treatments. The result clearly revealed that early stage weed control is essential for higher green pod yield in

Table 1. Effect of seedbed preparation and weed management practices on dehydrogenase and urease enzyme activity

Weed management practice	Dehydrogenase enzyme activity (µg triphenyl formazan (TPF) g^{-1} soil/day^{-1})						Urease enzyme activity (µg urea hydrolysed g^{-1}soil $4h^{-1}$)					
	Seed bed preparation (S)											
	15 DAS			30 DAS			15 DAS			30 DAS		
	Seed bed preparation											
	SSB	Normal seed bed	Mean	SSB	Normal seed bed	Mean	SSB	Normal seed bed	Mean	SSB	Normal seed bed	Mean
Dried banana leaf mulch 10 t/ha	4.44	4.21	4.33	5.01	3.11	4.06	355.2	379.7	367.5	392.1	446.4	416.3
Dried banana leaf mulch 10 t/ha *fb* PoE imazethapyr 50 g/ha at 25 DAS	4.81	3.87	4.34	6.59	3.46	5.03	360.1	384.8	372.4	371.7	476.2	424.3
Dried banana leaf mulch 10 t/ha *fb* PoE quizalofop-p-ethyl 50 g/ha at 25 DAS	4.50	4.04	4.27	6.64	6.03	6.34	359.2	370.0	365.0	447.3	476.2	461.7
PoE imazethapyr 50 g/ha at 15 DAS	4.47	4.31	4.39	3.38	3.69	3.54	387.2	372.3	379.8	359.2	392.1	375.7
PE Diclosulam *fb* PoE quizalofop-p-ethyl 50 g/ha at 25 DAS	3.29	2.77	3.03	3.32	3.69	3.56	386.6	419.1	403.0	444.8	519.4	482.1
PE Diclosulam *fb* HW at 25 DAS	3.11	2.88	3.00	3.71	3.50	3.60	428.9	452.1	440.5	476.7	479.1	477.4
Hand weeding at 20 and 40 DAS	3.57	3.05	3.31	3.87	3.86	3.87	362.8	330.6	346.6	457.6	384.4	419.5
Weedy check	2.88	2.73	2.81	3.54	3.10	3.32	380.0	348.0	364.0	346.2	316.6	331.4
Mean	3.82	3.55	0.35	4.53	3.79	0.55	377.6	382.1		411.6	435.5	
LSD (p=0.05)	Seed bed preparation (S)		0.18			0.27			NS			NS
	Weed management practices (W)		0.35			0.55			35.5			50.3
	Seed bed preparation X Weed management practices (S X W)		NS			0.78			NS			71.1

PE: pre-emergence, PoE: post-emergence, HW: Hand weeding, NS: non-significant

Table 2. Effect of seedbed preparation and weed management practices on total number of nodules per plant at 50% flowering stage, total weed density at 45 DAS and green pod yield of bush type vegetable cowpea

Weed management practices	Total no. of nodules per plant at 50 per cent flowering stage			Total weed density (no./m^2)			Green pod yield (t/ha)		
	Seed bed preparation								
	SSB	Normal seed bed	Mean	SSB	Normal seed bed	Mean	SSB	Normal seed bed	Mean
Dried banana leaf mulch 10 t/ha	8.53	8.67	8.50	3.61(12)	4.58(20)	4.12(16)	7.23	6.79	7.01
Dried banana leaf mulch 10 t/ha *fb* PoE imazethapyr 50 g/ha at 25 DAS	6.67	9.33	8.00	3.42(11)	4.99(24)	4.28(17)	7.48	7.19	7.34
Dried banana leaf mulch 10 t/ha *fb* PoE quizalofop-p-ethyl 50 g/ha at 25 DAS	12.00	13.67	12.83	4.22(17)	4.72(21)	4.51(19)	7.73	7.45	7.59
PoE imazethapyr 50 g/ha at 15 DAS	9.00	9.33	9.17	7.46(55)	7.71(59)	7.58(57)	5.49	4.72	5.10
PE Diclosulam *fb* PoE quizalofop-p-ethyl 50 g/ha at 25 DAS	18.67	7.67	13.17	5.55(30)	5.63(31)	559(30)	6.05	5.73	5.88
PE Diclosulam *fb* HW at 25 DAS	20.33	14.67	17.50	4.99(24)	7.42(54)	6.32(39)	5.99	5.28	5.63
Hand weeding at 20 and 40 DAS	12.67	7.00	9.83	6.39(40)	5.59(29)	5.97(35)	6.43	5.62	6.02
Weedy check	8.33	5.67	7.00	9.22(84)	11.24(126)	10.20(105)	3.90	2.33	3.11
Mean	12.00	9.50		5.92(34)	6.81(45)		6.29	5.64	
LSD (p=0.05)	Seed bed preparation (S)		0.67			0.29			0.18
	Weed management practices (W)		1.34			0.58			0.35
	Seed bed preparation X Weed management practices (SXW)		1.89			0.82			0.50

PE: Pre-emergence, PoE: post-emergence, HW: Hand weeding, Values in parentheses are original values and values are subjected to square root transformation $(\sqrt{x+1})$

cowpea. Due to initial slow growth of cowpea, weeds emerge fast and gain competitive advantage over the crop and caused reduction in pod yield.

It was concluded that the herbicides, PE diclosulam 12.5 g/ha and PoE quizalofop-p-ethyl 50 g/ha did not have any inhibitory effect on total number of nodules per plant, dehydrogenase and urease enzyme activity. However, PoE application of imazethapyr 50 g/ha showed reduction in the total number of nodules and an inhibition in the dehydrogenase and urease enzyme activity in soil.

REFERENCES

Casida LE, Klein DA and Santoo T. 1964. Soil dehydrogenase activity. *Soil Science* 98: 371–376.

Chatta MU, Ali A and Bilal M. 2007. Influence of planting techniques on growth and yield of spring planted sugarcane. *Pakistan Journal of Agriculture Science* **44**: 452–456.

Deepa L, Desai BK, Latha HS and Mahadevswamy. 2017. Biotoxic effect of diclosulam 84% WDG on growth, nodulation and nitrogen content of green gram. *International Journal of Agriculture Science* **9** (32): 4468–4470.

Kumawat P, Kaushik MK, Meena VK, Chouhan BS, Meena RK and Kumar R. 2017. Effect of weed management and fertility levels on productivity of cluster bean [*Cyamopsistetragonoloba* (L.) Taub]. *Legume Research* **40**(5): 884–889.

Latha PC and GopalG. 2010. Influence of herbicides on cellulolytic, proteolytic and phosphate solubilizing bacteria. *International Journal of Plant Protection* **3**(1): 83–88.

Majumdar B, Saha AR, Sarkar S, Maji B and Mahapatra BS. 2010. Effect of herbicides and fungicides application on fibre yield and nutrient uptake by jute (*Corchorus olitorius*), residual nutrient status and soil quality. *Indian Journal of Agricultural Science* **80**(10): 878–883.

Muthuram T, Krishnan R and Baradhan G. 2018. Productivity enhancement of irrigated green gram (*Vigna radiata*) through integrated weed management. *Plant Archives* **1**(18): 101–105.

Ramesh A, Joshi OP and Billore SD. 2000. Effect of herbicides on soil dehydrogenase and urease activity in soybean (*Glycine max*). *Indian Journal of Agricultural Science* **70**: 218–219.

Tehria SK, Rana SS and Kumar S. 2015. Nutrient uptake by weeds and pea as influenced by phosphorus and weed management. *Indian Journal of Weed Science* **47**(2): 144–149.

Walley F, Taylor A and Lupwayi. 2006. Herbicide effects on pulse crop nodulation and nitrogen fixation. *Farm Tech Proceedings*. pp. 121–123.

Watts GW and Crisp JD. 1954. Combined effect of cadmium and butachlor on soil enzyme activities and microbial community structure. *Environmental Geology* **51**: 1093–1284.

Yang YJ, Dungan RS, Ibekwe AM, Solano CV, Crohn DM and Crowley DE. 2003. Effect of organic mulches on soil bacterial communities one year after application. *Biology and Fertility of Soils* **38**: 273–281.

Yang YZ, Liu S, Zheng D and Feng S. 2006. Effects of cadmium, zinc and lead on soil enzyme activities. *Journal of Environmental Science* **18**: 1135–1141.