International Journal of Plant & Soil Science

34(20): 447-453, 2022; Article no.IJPSS.87256
ISSN: 2320-7035

Bio-efficacy of Herbicides with Different Water Volumes and Spray Timing under Zero Tillage Rice Residue Retention Scenario against *Phalaris minor* in Wheat

Ankur Chaudhary [a*], Dharam Bir Yadav [a], Samunder Singh [a], Todar Mal Poonia [a], Satbir Singh Punia [a] and Narender Singh [a]

[a] *Department of Agronomy, CCS Haryana Agricultural University, Hisar, Haryana-125004, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2022/v34i2031174

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/87256

Original Research Article

Received 14 March 2022
Accepted 28 May 2022
Published 25 June 2022

ABSTRACT

Background: Continuous use of the similar modes of action-based herbicides leads to the development of herbicide resistance in wheat-associated weeds in north-west India. Accelerated development of multiple resistance against most of the available post-emergence herbicides emphasize the use of pre-emergence herbicides. But, the efficacy of pre-emergence herbicide is a matter of concern as surface retained stubbles and/or straw alter herbicide efficacy associated with a direct interception of herbicide.
Methods: A field study was conducted for two *rabi* seasons (2018-19 and 2019-20) to optimize spray volume and time of application for improving the bio-efficacy of pre-emergence herbicides under zero tillage full rice residue scenario. The herbicidal treatments (g/ha) included pendimethalin + pyroxasulfone (1000.0+127.5) as pre-emergence (PE), pyroxasulfone (127.5) as PE, pyroxasulfone (127.5) as early post emergence (EPoE), aclonifen+diflufenican (1002+200) EPoE, halauxifen methyl+ fluroxypyr (7.3+233.4) as EPoE, flumioxazin (100) as PE with two different water volumes 500 and 1000 liter/ha along with pendimethalin *fb* pinoxaden (1500+50) in 500 l/ha water volume, pendimethalin (1500) as PE in 375 l/ha water volume, weed free and weedy check.
Results: The present study showed that pendimethalin + pyroxasulfone as PE with a higher spray

Corresponding author: E-mail: ankurchaudhary292@gmail.com;

volume of 1000 l/ha and alone application of pyroxasulfone as EPoE produced similar *Phalaris minor* control as with pendimethalin *fb* pinoxaden (PE *fb* Post) under full rice residue scenario in zero-till wheat.

Keywords: Herbicide resistance; Phalaris minor; pre-emergence; residue retention; wheat.

1. INTRODUCTION

Rice-wheat is the most important cropping system in India. Sustainability issues such as depletion of groundwater, extensive rice residue burning, deterioration of soil structure, accelerated development of wheat associated weeds and escalating cost of cultivation are halting the potential productivity of this system [1,2,3]. The wheat crop is infested by many weeds which includes grasses as well as broadleaf weeds. Among grassy weeds, *Phalaris minor, Avena ludoviciana, Polypogon monspeliensis and Poa annua*, while, important broad leaved weeds are *Chenopodium album, C. murale, Coronopus didymus, Rumex dentatus, R. spinosus, Anagallis arvensis, Melilotus indica, Medicago denticulata, Malva parviflora* and *Convolvulus arvensis* [4]. *Phalaris minor* (littleseed canarygrass) is morphologically similar to wheat plants in its vegetative phase and shows a more competitive nature against wheat in resource acquisition. The problem of *Phalaris minor* is primarily concentrated in the rice-wheat cropping system that is being followed in Indo-Gangetic Plains.

In the rice-wheat system, continuous use of the same herbicides isoproturon to control *P. minor* in wheat has resulted in the development of resistant biotypes in northwest India [2,5]. The first case of resistance in *P. minor* to isoproturon was reported in 1995 in India [6] and over the years the same has evolved multiple and cross-resistance against the used herbicides [7]. The accelerated development of herbicide resistance in wheat-associated weed has become a severe threat to the sustainable production of wheat. Moreover, when initial high populations of *P. minor* were exposed to poor spray techniques, and then it enhanced the probability of development of herbicide resistance by imposing strong selection pressure [8]. In addition to it, overuse of herbicides of the same mode of action has resulted in the evolution of cross and multiple herbicide resistance against most of the available post-emergence herbicides [2,9]. So, there is a need to emphasize the use of pre-emergence herbicides along with post-emergence for better weed control.

Further, farmers' in northwest India burn both rice and wheat residue in fields resulting in severe losses to ecological health [3]. However, with the development of efficient seeders such as happy seeder, and rotary disk drill, now it is become feasible to drill wheat seed under partial or full rice residue conditions [10]. The retention of rice residue on the surface provides congenial environment to the succeeding wheat crop with thermo moderating effect, more moisture conservation and prevention of weed emergence to some extent [3]. However, the tangible effects are varying with the amount of residue, nature of residue and position of residue (retention/incorporation). Further, the efficacy of pre-emergence herbicide is a matter of concern as surface retained stubbles and/or straw alter herbicide efficacy associated with a direct interception of herbicide, accumulation of high organic matter and acceleration of microbial activity under such conditions [11,12]. Earlier, [11] reported only 30% of the applied herbicide reached the soil in the presence of 2.2 t/ha of straw on the surface, whereas less than 10% reached when straw amount raised to 4.48 t/ha and reduced herbicidal action of acetochlor, alachlor, and metolachlor. So, higher doses could be required for effective control of weeds under such scenario. Similarly, [12] reported the effect of trifluralin (non-water-soluble) and pyroxasulfone (water-soluble) on rigid ryegrass improved from 53 to 78% with increasing carrier volume associated with greater coverage resulting in higher weed and chemical contact. Herbicides efficacy under two contrasting conditions ZT and CT is likely to differ enormously due to the presence of stubbles/straw, level of organic matter, variable level of microbial driven metabolism, nature of herbicides (solubility), seeding depth and weed flora [3]. Hence, there is a need to optimize herbicidal dose, formulation, scheduling (pre-planting or before irrigation/early post) and spray volume for adequate weed control in wheat under paddy straw retention conditions [3]. Therefore, this study was planned to screen out herbicides with alternate modes of action and or tank-based mixtures for effective weed control in wheat to ensure higher productivity under residue retained conditions. The study was conducted for two *rabi* seasons (2018-19 and 2019-20) with the objective to optimize spray volume and application time for improving the bio-efficacy of pre-emergence herbicides under the zero tillage full rice residue scenario.

2. MATERIALS AND METHODS

The present study was conducted at CCS Haryana Agricultural University Regional Research Station, Uchani, Karnal during *rabi* 2018-19 and 2019-20. The climate of the Karnal region is characterized by hot and dry summer with cold winter. Agro-meteorological data for the wheat seasons are provided in Figs. 1 and 2. The experimental field's soil was clay loam and near neutral with low organic carbon, low in available nitrogen, medium in available phosphorus and high in potassium.

The experiment was laid out in a randomized block design with three replications. The herbicidal treatments (g a.i./ha) included pendimethalin + pyroxasulfone (1000.0+127.5) as pre-emergence (PE), pyroxasulfone (127.5) as PE, pyroxasulfone (127.5) as early post emergence (EPoE), aclonifen+diflufenican (1002+200) EPoE, halauxifen methyl+ fluroxypyr (7.3+233.4) as EPoE, flumioxazin (100) as PE with two different water volumes 500 and 100 liter (L) along with pendimethalin *fb* pinoxaden (1500+50) in 500 L water volume, pendimethalin (1500) as PE in 375 L water volume, weed free and weedy check. During *rabi* 2019-20, mesosulfuron+idosulfuron herbicide (14.4 g/ha) was used in replacement of aclonifen+diflufenican (1002+200). The herbicides were sprayed at pre-emergence stage and early post-emergence stage (one day before first irrigation) with the different spray volumes of water. In weed free treatment, hand weeding was done whenever required and no weed management practice was taken in weedy check plots. The wheat *cv* 'HD 2967' and 'WH 1105' were sown on 6 November 2018 and 7 November 2019 and harvested on 17 April and 20 April during 2018-19 and 2019-20, respectively. Wheat was sown using happy seeder with retention of full rice residue about 6-7 t/ha after harvesting the rice. The seed rate was 100 kg/ha and the crop was sown with a row spacing of 20 cm. All other management practices were followed as per the recommended package and practices by the university. The weed samples were collected at 75 DAS

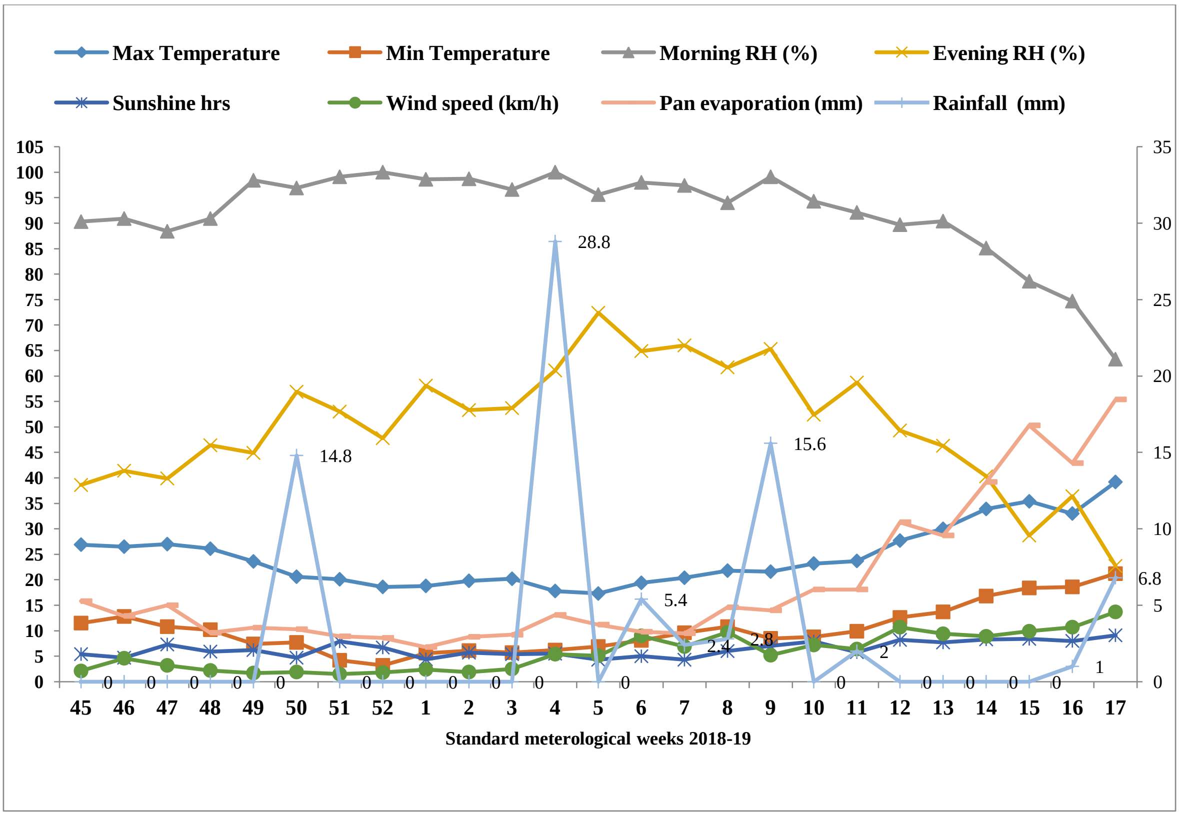

Fig. 1. Weekly weather data of experimental site during *rabi* 2018-19

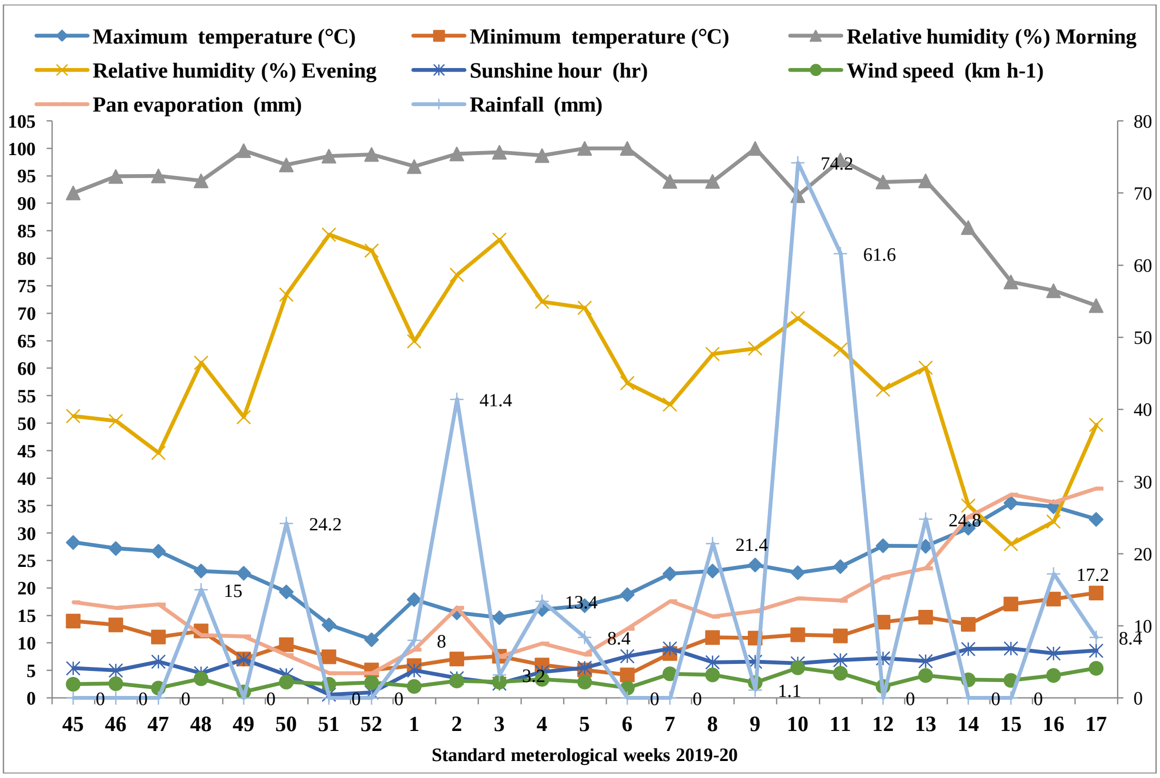

Fig. 2. Weekly weather data of experimental site during *rabi* 2019-20

of the crop with the help of a quadrant (0.5 x 0.5 m) from two places in a random manner from each plot. Each weed sample was separated as *P. minor* and counted as number of plants/m2. Weeds from each plot were first sundried and thereafter kept in the oven at 65ºC until a constant weight was achieved. The crop yield data was recorded at harvest. The statistical analysis was made with the help of OPSTAT software. The significance of the treatments was tested at 5% level of significance.

3. RESULTS AND DISCUSSION

3.1 Weed Density and Dry Weight

The wheat crop was infested primarily by *Phalaris minor* among grassy weeds, while, *Medicago denticulate*, *Rumex dentatus* and *Coronopus didymus* among broad-leaved weeds (BLWs) during both the years of study. During 2018-19, significantly lower *P. minor* density was observed with EPoE application of aclonifen+diflufenican which was statistically found at par with pre application of pyroxasulfone but significantly higher than the of the treatments for their original values (Table 1). During 2019-20, minimum *Phalaris minor* density was found with tank mix application of pendimethalin+pyroxasulfone as PE with water volume 1000 L which was statistically at par with EPoE application of pyroxasulfone alone for both water volumes along with pendimethalin *fb* pinoxaden (Table 2).

P. minor dry weight (g/m^2) was observed significantly lower with EPoE application of aclonifen +diflufenican (2.6-4.5 g/m^2) which was found at statistically at par with pendimethalin+pyroxasulfone as PE (5.2-6.5 g/m^2), alone application of pyroxasulfone as PE (4.7-5.5 g/m^2) along with pendimethalin *fb* pinoxaden (7.1 g/m^2) during *rabi* 2018-19. Application of pyroxasulfone as alone or in combination with pendimethalin provided effective control of *P. minor* as compared to halauxifenmethyl+fluroxypyr (23.3-28.3 g/m^2), flumioxazin (17.1-22.6 g/m^2), alone pendimethalin (16.3 g/m^2) and effects were more pronounced at higher water volume (Table 1). During *rabi* 2019-20, significantly lowest *P. minor* dry matter was recorded with pyroxasulfone (3.03 g/m^2) as EPoE, being at par with PE application of pendimethalin+pyroxasulfone (3.13 g/m2), alone application of pyroxasulfone as PE (4.1-4.8 g/m^2) along with along with pendimethalin *fb* pinoxaden (4.0 g/m^2). Overall pyroxasulfone application (Table 2) either alone

(3.0-4.8 g/m^2) or in tank mix with pyroxasulfone (3.1-4.1 g/m^2) significantly reduced *P. minor* infestation as compared halauxifen methyl+fluroxypyr (19.3-20.5 g/m^2) and weedy check (25.80 g/m^2). These results were found in line with the earlier findings of [12] as spray coverage significantly increased with increasing carrier volume from 4.8% for 30 L/ha to 23% for 150 L/ha. Pyroxasulfone is a new herbicide and acts as a root/shoot growth inhibitor in germinating seedlings of susceptible weeds [13]. Besides spray volume, the nature of nozzle could also matters for obtaining desired efficacy of herbicides. [14] Investigated that 61.3% of farmers reported low weed infestation when they used recommended flood jet and flat fan types of nozzles are the most used nozzles for high volume spray.

3.2 Yield

During *rabi* 2018-19 (Table 1), the higher wheat grain yield (5719-5728 kg/ha) was recorded with PE application of pendimethalin + pyroxasulfone spray volume of 500-1000 l/ha which was found at par with sole application of pyroxasulfone as early PoE as either 500 l/ha (5588 kg/ha) or EPoE (5498 kg/ha), but significantly higher to halauxifen methyl+ fluroxypyr as EPOE (5018-5067 kg/ha), flumioxazin (5162-5214 kg/ha), alone pendimethalin (5200 kg/ha) and alone application of pyroxasulfone as PE (5247-5441 kg/ha), but at par with pendimethalin *fb* pinoxaden (5666 kg/ha). Aclonifen+diflufenican treatments were superior to the rest of the treatments in reducing *P. minor* dry weight (2.6-4.5 g/m^2), but showed some phyto-toxicity on the wheat crop (20-25%) at the initial stage which was recovered later and the same was reflected in its yield (5220-5473 kg/ha).

During *rabi* 2019-20, significantly highest grain yield (Table 2) was observed with pendimethalin *fb* pinoxaden (5966 kg/ha), which was found statistically at par with pendimethalin + pyroxasulfone with PE (5717-5867 kg/ha) and alone application of pyroxasulfone as EPoE (5700 kg/ha) with higher water volume. While significantly lower grain yields were observed with halauxifen methyl+ fluroxypyr (4600-4616 kg/ha) as EPoE and flumioxazin (5116-5383 kg/ha) as PE.

[15] also reported pyroxasulfone at 127.5 g/ha had provided effective control of *P. minor* and resulted in the highest wheat grain yield (4.80-5.43 t/ha) in farmer's fields. Similar results were also reported by [16] to manage resistant and susceptible rigid ryegrass in Australia. The results from the present study showed that pendimethalin + pyroxasulfone as PE with higher spray volume 1000 L/ha and alone application of pyroxasulfone as EPoE produced similar *P. minor* control as with pendimethalin *fb* pinoxaden (PE *fb* Post) under full rice residue scenario in wheat.

Table 1. Effect of herbicides spray volumes and time of application on weed density, weed dry matter (g/m^2) at 75 DAS and grain yield (kg/ha) in wheat during *rabi* 2018-19

Treatments	Dose (g/ha)	Time	Water vol. (L/ha)	*P. minor* density (no./m^2) 75 DAS	*P. minor* dry weight (g/m^2) 75 DAS	Grain yield (Kg/ha)
Pendimethalin + pyroxasulfone	1000.0+127.5	PE	500	2.96(8.0)	6.5	5719
Pendimethalin + pyroxasulfone	1000.0+127.5	PE	1000	3.21(9.3)	5.2	5728
Pyroxasulfone	127.5	PE	500	2.76(6.7)	11.6	5441
Pyroxasulfone	127.5	PE	1000	3.08(8.7)	11.4	5247
Pyroxasulfone	127.5	*EPoE	500	3.36(10.7)	5.5	5588
Pyroxasulfone	127.5	EPoE	1000	3.21(9.3)	4.7	5498
Aclonifen+diflufenican	1002+200	EPoE	500	2.20(4.0)	4.5	5220
Aclonifen+diflufenican	1002+200	EPoE	1000	1.73(2.0)	2.6	5473
Halauxifen methyl+ fluroxypyr	7.3+233.4	EPoE	500	6.29(38.7)	23.3	5067
Halauxifen methyl + fluroxypyr	7.3+233.4	EPoE	1000	6.03(35.3)	28.3	5018
Flumioxazin	100	PE	500	4.65(20.7)	17.1	5162
Flumioxazin	100	PE	1000	3.63(12.7)	22.6	5214

Treatments	Dose (g/ha)	Time	Water vol. (L/ha)	*P. minor* density (no./m^2) 75 DAS	*P. minor* dry weight (g/m^2) 75 DAS	Grain yield (Kg/ha)
Pendimethalin *fb* Pinoxaden	1500+50	PE *fb* PoE	500	3.62(12.7)	7.1	5666
Pendimethalin	1500	PE	375	3.31(10.0)	16.3	5200
Weed free				1.00(0.0)	0.00	6048
Weedy check				6.34(39.3)	64.9	4784
LSD (p=0.05)				0.75(5.13)	4.9	220

Original values (in parentheses) are subjected to square root transformation before data analysis
** EPoE spray before first irrigation; PE- Just after sowing*

Table 2. Effect of herbicide spray volume and time of application on weed density, weed dry matter (g/m^2) at 75 DAS and grain yield (kg/ha) in wheat during *rabi* 2019-20

Treatments	Dose (g/ha)	Time	Water vol. (L/ha)	*P. minor* density (no./m^2)	*P. minor* dry weight (g/m^2)	Grain yield (kg/ha)
Pendimethalin + pyroxasulfone	1000.0+127.5	PE	500	3.3 (10.0)	4.07	5717
Pendimethalin + pyroxasulfone	1000.0+127.5	PE	1000	2.5 (5.3)	3.13	5867
Pyroxasulfone	127.5	PE	500	3.9 (14.7)	4.27	5367
Pyroxasulfone	127.5	PE	1000	4.0 (15.3)	4.13	5516
Pyroxasulfone	127.5	*EPoE	500	3.6 (12.0)	4.40	5483
Pyroxasulfone	127.5	EPoE	1000	3.4 (10.7)	3.03	5700
Mesosulfuron+ idosulfuron	14.4	EPoE	500	5.8 (33.3)	10.27	4950
Mesosulfuron+ idosulfuron	14.4	EPoE	1000	4.3 (18.0)	7.53	5266
Halauxifen methyl+ Fluroxypyr	7.3+233.4	EPoE	500	8.3 (68.0)	20.53	4600
Halauxifen methyl + Fluroxypyr	7.3+233.4	EPoE	1000	7.1 (50.7)	19.27	4616
Flumioxazin	100	PE	500	6.3 (38.7)	9.73	5116
Flumioxazin	100	PE	1000	4.3 (18.7)	5.53	5383
Pendimethalin *fb* Pinoxaden	1500+50	PE *fb* PoE	500	3.0 (8.67)	3.93	5966
Pendimethalin	1500	PE	375	5.5 (30.0)	9.67	4650
Weed free				0.00 (1.0)	0.00	6017
Weedy check				7.5 (55.3)	25.80	3633
LSD (p=0.05)				0.8 (9.11)	6.89	386

Original values (in parentheses) are subjected to square root transformation before data analysis
**EPoE spray before first irrigation; PE- Just after sowing*

4. CONCLUSIONS

Herbicide resistance is a worldwide phenomenon and the number of resistant biotypes of weeds is increasing at an alarming rate. From the results of this experiment, it can be concluded that alternate herbicides such as sole application of pyroxasulfone either as PE and EPoE along with its combined application with pendimethalin as pre-emergence with higher water volume may be integrated with other weed management practices under rice residue retention scenario in wheat. Further, research efforts are needed to optimize herbicidal dose, formulation, scheduling (pre-planting or before irrigation/early post) and spray volume for effective weed control in wheat under paddy straw retention conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Chauhan BS, Mahajan G, Sardana V, Timsina J, Jat ML. Productivity and sustainability of the rice–wheat cropping system in the Indo-Gangetic Plains of the Indian subcontinent: problems, opportunities, and strategies. Adv. Agron. 2012;117:315-369.
2. Chhokar RS, Chaudhary A, Sharma RK. Herbicide resistant weeds in India and their management. In Fifty Years of Weed Science Research in India. (Eds. Kumar, S., Mishra, J.S.). Indian Society of Weeds Science, Jabalpur, India. 2018;288-308.
3. Chaudhary A, Chhokar RS, Yadav DB, Sindhu VK, Ram H, Rawal S, Khedwal RS, Sharma RK, Gill SC. In-situ paddy straw management practices for higher resource use efficiency and crop productivity in Indo-Gangetic Plains (IGP) of India. J Cereal Res. 2019;11:172-198.
4. Chhokar RS, Sharma RK, Sharma I. Weed management strategies in wheat-A review. J Wheat Res. 2012;4(2):1-21.
5. Malik RK, Singh S. Evolving strategies for herbicide use in wheat. Resistance and integrated weed management. In: Proceeding of International Symposium. Indian Society of Weed Science, Hisar, India. 1993;I:225-238.
6. Singh S, Malik RK, Balyan RS, Singh S. Distribution of weed flora of wheat in Haryana. Indian J Weed Sci. 1995;27:114-121.
7. Dhawan RS, Punia SS, Singh S, Yadav D, Malik RK. Productivity of wheat (*Triticum aestivum*) as affected by continuous use of new low dose herbicides for management of littleseed canarygrass (*Phalaris minor*) in India. Indian J Agron. 2009;54:58-62.
8. Singh R, Yadav DB, Yadav A, Punia SS. Characterization of herbicide use and factors responsible for herbicide resistance in *Phalaris minor* in wheat in Haryana, India. Crop Prot. 2021;144:105581.
9. Chhokar RS, Sharma RK. Multiple herbicide resistance in littleseed canarygrass (*Phalaris minor*): a threat to wheat production in India. Weed Biol Manage. 2008;8:112-123.
10. Sidhu HS, Manpreet S, Humphreys E, Singh Y, Singh, B, Dhillon SS, Blackwell J, Bector V, Malkeet S, Sarbjeet S. The Happy Seeder enables direct drilling of wheat into rice stubble. Aust. J. Exp. Agric. 2007;47:844-854
11. Banks AP, Robinson EL. Soil reception and activity of acetochlor, alachlor, and metolachlor as affected by wheat (*Triticum aestivum*) straw and irrigation. Weed Sci.1986;34 (3):607–611.
12. Borger CP, Riethmuller GP, Ashworth M, Minkey D, Hashem A, Powles SB. Increased carrier volume improves preemergence control of rigid ryegrass (*Lolium rigidum*) in zero-tillage seeding systems. Weed Technol. 2013;27(4):649-655.
13. Tanetani Y, Kaku K, Kawai K, Fujioka T, Shiminizu T. Action mechanism of a novel herbicide, pyroxasulfone. Pestic. Biochem. Phys. 2009;95:47–55.
14. Dhaliwal HS, Singh R, Brar LS. Impact analysis of factors affecting *Phalaris minor* infestation in wheat in Punjab. Indian J. Weed Sci. 2007;39(182):66-73.
15. Kaur T, Bhullar MS, and Kaur S. Control of herbicide resistant *Phalaris minor* by pyroxasulfone in wheat. Indian J. Weed Sci. 2019;51(2):123-128.
16. Walsh MJ, Fowler TM, Crowe B, Ambe T, Powles SB. The potential for pyroxasulfone to selectively control resistant and susceptible rigid ryegrass (*Lolium rigidum*) biotypes in Australian grain crop production systems. Weed Technol. 2011; 25:30–37.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/87256