Indian Journal of Agricultural Sciences **94** (1): 074–079, January 2024/Article
https://doi.org/10.56093/ijas.v94i1.143436

Controlling *Phalaris minor* with novel pyroxasulfone under conservation agriculture in the north-western Indo-Gangetic Plains

SUNIL KUMAR[1] and RAMANJIT KAUR[1]*

ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India

Received: 09 October 2023; Accepted: 06 November 2023

ABSTRACT

A field experiment was conducted during the winter (*rabi*) seasons of 2021–22 and 2022–23 at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi to evaluate the effectiveness of pyroxasulfone in controlling resistant *Phalaris minor* within the maize (*Zea mays* L.)-wheat (*Triticum aestivum* L.) cropping system. The experiment consisted a split-plot design involving 3 crop establishment systems (Bed + R; ZT + R and CT + R) and 5 weed management strategies, viz. pyroxasulfone (W_1); pyroxsulfone *fb* metsulfuron + carfentrazone (W_2); Sulfosulfuron + metsulfuron (W_3); UWC (W_4); and WFC (W_5), replicated thrice. The results from two-year analysis consistently favoured bed planting with residue, which exhibited the lowest *P. minor* density and total weed population compared to the other two methods with highest weed control efficiency. Among the various weed management options, the combination of pyroxasulfone *fb* metsulfuron + carfentrazone recorded significantly lowest *P. minor* density and higher weed control efficiency, similar to the weed-free check. Additionally, this treatment led to significantly higher dry matter accumulation (68.2 g/m^2), ear length (12 cm), test weight (41 g) and grain yield (5.8 t/ha) compared to other herbicide treatments, underscoring its outstanding performance.

Key words: *Phalaris minor*, Pyroxasulfone, Wheat, Weed control efficiency, Weed index

Wheat (*Triticum aestivum* L.) holds a prominent position in temperate countries, serving as a vital source not only for human consumption but also for livestock feed. The success of wheat cultivation hinges on its adaptability to varying environmental conditions and the implementation of effective agronomic practices. Despite numerous factors influencing wheat productivity, one often underestimated factor contributing to reduced yields is the presence of weeds (Chaudhary *et al.* 2022). Weeds can cause yield losses ranging from 10 to as high as 82%, depending on factors such as weed density, weed species, timing of infestation, and the competitive abilities of the crop against these weeds within different agro-ecological contexts (Heyne 1987). Extensive research has been conducted on weed management in wheat production, with some studies highlighting the significant challenges posed by wild oat (*Avena ludoviciana*) and wild canary grass (*Phalaris minor*). These two grassy weeds are considered major obstacles to successful wheat cultivation, frequently resulting in lower yields (Singh *et al.* 1995).

Phalaris minor is a major problem in north western Indo-Gangetic plain, and this weed have shown resistant against many herbicides due to single use of herbicides for many years after green revolution. Their control is especially challenging due to initial morphological and physiological similarities with wheat plants, as well as an extended emergence phase. Singh *et al.* (2016) documented limited effectiveness of sulfosulfuron in combatting canary grass, along with evidence of resistance in a population sourced from a farmer's field towards clodinafop and fenoxaprop. The challenge posed by herbicide-resistant weeds is particularly pronounced in developing countries due to the limited availability of alternative herbicides for effective management. Although zero tillage is the most successful resource conservation technology, these weeds are the major challenges because of severe infestation and shifting while switching from conventional tillage to conservation tillage in the initial years of adoption (Das 2018). A dynamic integrated weed management strategy involving bed planting, zero-tillage, residue mulch, diversified crop rotations and herbicides is highly essential for arresting weed interference and crop yield losses during initial years of adoption of conservation agriculture (CA) (Ghosh *et al.* 2021). Therefore, this study has been planned to overcome the problem of resistant *P. minor* using a novel herbicide pyroxasulfone in maize (*Zea mays* L.)-wheat cropping system.

MATERIALS AND METHODS

A field experiment was conducted during the winter

[1]ICAR-Indian Agricultural Research Institute, New Delhi.
*Corresponding author email: ramanjitagro@gmail.com

(*rabi*) seasons of 2021–22 and 2022–23 at the research farm of ICAR-Indian Agricultural Research Institute (28º 40'N, 77º 11'E and about 228 m msl) New Delhi. The experimental farm used in the present study was under a maize-wheat cropping system. The soil of the experimental field was sandy-loam and alkaline in nature (*p*H 7.7), with EC 0.47 dS/m, low in organic carbon (0.41%) and available nitrogen (231 kg/ha), and medium in available phosphorus (18 kg/ha) and potash (241.1 kg/ha). The experiment was laid out in a split plot design (SPD) with the main plot having 3 crop establishment systems i.e. bed planting (FIRB) + residue; zero tillage (ZT) + residue; and conventional tillage (CT) + residue and sub plots consists of 5 weed management options i.e. pyroxasulfone 85 WG @0.15 kg/ha as pre-emergence (W_1); Pyroxasulfone @0.15 kg/ha (PE) *fb* (metsulfuron + carfentrazone) @0.05 kg/ha as post-emergence (W_2); Sulfosulfuron + metsulfuron @0.04 kg/ha as post emergence (W_3); weedy check (UWC) (W_4); and weed free check (WFC) (W_5) with total 15 treatment combinations and replicated thrice. The wheat variety HD 3226 was used in the experiment. This variety is released for commercial cultivation in north western Plain zone comprising of Punjab, Haryana, Delhi, Rajasthan (Kota and Udaipur), western Uttar Pradesh and Una district and Ponta valley of Himachal Pradesh. The average yield of HD 3226 is 57.5 q/ha while potential yield is 79.60 q/ha. This variety is highly resistant to yellow, brown, black rust, Karnal bunt, powdery mildew, loose smut and foot rot. The recommended dose of fertilizers @150: 60: 60 nitrogen: phosphorous: potassium kg/ha was applied with 33% N, full dose of P and K as basal, while rest of N was applied in two equal splits at vegetative stage and flowering stage in all the treatments. Rest all the operations were followed as per the package of practices for growing wheat crop.

Weed control efficiency (WCE) was calculated to assess the efficacy of various weed control treatments based on their effect on weed density (Das 2018):

$$\text{WCE} = \frac{\text{WP}_\text{C} - \text{WP}_\text{T}}{\text{WP}_\text{C}} \times 100$$

The weed index (WI) was calculated to measure crop yield loss across weed control treatments in comparison to the weed free plot (Gill and Vijaykumar 1969) as:

$$\text{WI} = \frac{\text{Y}_\text{WF} - \text{Y}_\text{T}}{\text{Y}_\text{WF}} \times 100$$

where, Y_{WF} is the crop yield (t/ha) in weed free check plot and Y_T is the crop yield (t/ha) in treated plot for which WI is to be worked out. Residue*: maize residue was used in wheat.

Dry matter accumulation was calculated based on samples randomly collected within a quadrat size of 0.25 m × 0.25 m. The samples were thoroughly dried at 65 to 70°C. The results were then converted to a per square meter basis and measured in grams and then converted on the bases of 1 m^2 area and measured in grams. Likewise, samples were collected to assess yield from an area measuring 4 m × 4 m and after sun drying, the yield was converted into a per hectare basis. For test weight, seed samples were randomly collected from lot and weighed the 1000-seeds in grams. Data on weed density were transformed through square-root method (x +0.5) before analysis of variance (ANOVA). The ANOVA of weed data was done in a split-plot design using PROC GLM in SAS 9.3 (SAS Institute, Cary, NC). A least significant difference (LSD) test was carried out to appraise the significance of treatment means at $P \leq 0.05$.

RESULTS AND DISCUSSION

Weed interference: The weed composition in the field encompasses grassy weeds (*P. minor* and *A. loduviciana*) and broad-leaf weeds (*Coronopus didymys, Chenopodium album, Melilotus indica, Anagellis arvensis*, and *Rumex dentatus*). An integrated analysis of two years of pooled data (Table 1) demonstrates that the lowest populations (no./m^2) of *P. minor* (1.02) and total weed flora (both grassy and broad-leaved weeds) (3.1) were observed in the bed planting with residue (R) management strategy, as opposed to zero tillage (ZT+R) and conventional tillage (CT) with residue (R). The reduced density of *P. minor* and total weed density in bed planting with residue can be attributed to the limited available surface area for weed growth, as suggested by Ghosh *et al.* (2022). Additionally, the residue obstructs light penetration, which hampers weed germination and suppresses overall weed growth, as indicated by Raj *et al.* (2022). Ghosh *et al.* (2021) also observed that flatbed planting led to reduced total weed density (12.7 no./m^2) and dry matter (8.65 g/m^2) at 30 days after sowing (DAS) in New Delhi. Their findings indicated a significantly lower density of grassy weeds at 30 DAS when employing the Permanent Broad Bed (PBB + R) during both years of wheat cultivation. Sharma *et al.* (2023) concluded that conventional tillage (CT) using flat-bed planting resulted in higher weed density (148/m^2) and weed dry matter (2.40 g/m^2) compared to conservation agriculture (CA) treatments. Among the various weed management options, the lowest densities of *P. minor* and total weeds (both grassy and broad-leaved) were observed in the weed-free check treatment, surpassing all other treatments. In the case of herbicide treatments, the sequential application of pyroxasulfone *fb* metsulfuron+carfentrazone (W_2) resulted in the lowest density of *P. minor* (0.71) and total weeds (2.8), comparable to the weed-free check (W_5). This effectiveness can be attributed to pyroxasulfone's control of weeds, particularly *P. minor*, as it functions as a pre-emergence herbicide (very long chain fatty acid synthesis inhibitor), creating a weed-free environment for the crop. In the study conducted in Punjab, Kaur *et al.* (2019) found that the pre-emergence application of pyroxasulfone at a rate of 127.5 g/ha resulted in the lowest density of *Phalaris minor* (1.38 no./m^2), the lowest dry matter of weeds (1.73 g/m^2), and the highest weed control efficiency (99.0%). Subsequently, emerging weeds were managed through post-emergence herbicides

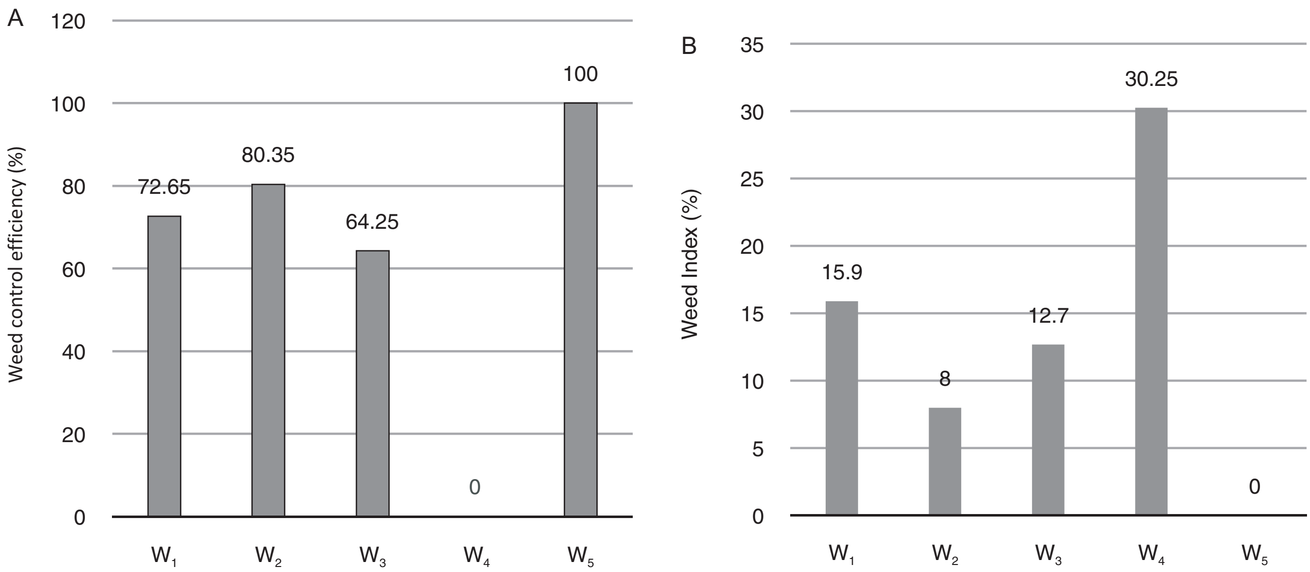

Fig. 1 Total weed control efficiency (%) and weed index (%). Treatment details are given under Materials and Methods.

Table 1 Effect of weed management options and crop establishment methods on density and control efficiency of *Phalaris minor* and total count of weeds at 40 days after sowing (DAS)

Treatment	*Phalaris minor* (no./m^2)			Weed control efficiency (%)			Total weed count* (no./m^2)		
Year	2021–22	2022–23	Pooled data	2021–22	2022–23	Pooled data	2021–22	2022–23	Pooled data
Crop establishment methods (C)									
Bed + residue	1.06	0.99	1.02	73.9	75.3	74.6	3.2 (12)	3.1 (12)	3.1 (12)
ZT + residue	1.15	1.14	1.14	70.6	73.5	72.0	3.6 (16)	3.3 (14)	3.5 (15)
CT + residue	1.18	1.17	1.17	70.0	68.9	69.4	3.6 (16)	3.4 (15)	3.5 (15)
SEm±	0.03	0.03	0.02	2.0	1.6	1.3	0.1	0.1	0.1
LSD (P=0.05)	NS	0.11	0.08	NS	6.3	4.2	0.2	NS	0.2
Weed management options (W)									
W_1	0.94	0.94	0.94	87.0	88.6	87.8	3.5 (12)	3.1 (9)	3.3 (11)
W_2	0.71	0.71	0.71	100.0	100.0	100.0	3.0 (8)	2.7 (7)	2.8 (8)
W_3	1.25	1.15	1.20	70.4	74.3	72.3	3.9 (15)	3.8 (14)	3.8 (14)
W_4	2.04	2.00	2.02	0.0	0.0	0.0	6.2 (38)	6.1 (37)	6.1 (38)
W_5	0.71	0.71	0.71	100.0	100.0	100.0	0.7 (0)	0.7 (0)	0.7 (0)
SEm±	0.06	0.06	0.04	3.0	3.6	2.4	0.1	0.1	0.1
LSD (P=0.05)	0.16	0.18	0.12	8.8	10.5	6.9	0.4	0.4	0.3

Treatment details are given under Materials and Methods. *Data are square-root transformed $(x+0.5)^{1/2}$ values in the parenthesis are original means.

like metsulfuron+carfentrazone. The combination of pre- and post-emergence herbicides proved to be highly effective in weed control, aligning with the findings of Kaur and Singh (2019), and Kumar *et al.* (2022).

Weed control efficiency (%): While assessing various crop establishment methods, statistically non-significant variation was observed in overall weed control efficiency. However, it's noteworthy that bed planting with residue exhibited superior weed control efficiency compared to alternative methods. When focusing on the specific case of *Phalaris minor*, a significantly higher level of weed control efficiency was achieved in bed planting with residue, surpassing both zero tillage (ZT) and conventional tillage (CT) methods. This outcome can be attributed to the reduced weed density, particularly of *Phalaris minor*, in the bed planting system (Ghosh *et al.* 2022). Regarding herbicide application, W_2, involving pyroxasulfone metsulfuron and carfentrazone, demonstrated the highest weed control efficiency at an impressive 100%, compared to the weed-free check (W_5) in case of *P. minor* (Table 1). This exceptional performance can be attributed to the comprehensive control of *Phalaris minor* achieved with the W_2 treatment compared to other herbicide regimens. In their field experiment aimed at evaluating the efficacy of different herbicides in wheat, Kaur *et al.* (2019) discovered that the application of pyroxasulfone at rates of 127.5 g/ha and 102 g/ha yielded the best control of *Phalaris minor* compared to other herbicides. The highest dose of 127.5 g/ha of pyroxasulfone demonstrated the most effective control of *Phalaris minor*, achieving control rates of 100 and 98.8% in two-years of the study. Following closely, the application of pyroxasulfone at 102 g/ha and pendimethalin yielded control rates of 96.3 and 93.8%, respectively, in both years, then other treatments. But in case of overall weed control efficiency (Fig. 1a pooled data of two year) at 40 DAS, significantly highest weed control efficiency (80.35%) was recorded in pyroxasulfone *fb* metsulfuron + carfentrazone in both the year of experimentations, compared to other herbicide options. These findings align with prior research by Kaur and Singh (2019) and Kumar *et al.* (2022).

Weed index (%): The weed index measures reduction in crop yield under different treatments due to presence of weeds in comparison to weed free plot. The reduction in yield was ranging from 8 to as high as 30.2% (Fig. 1b) in pooled data of two years, because of the weed infestation observed under different weed control treatments. Pre-emergence application of pyroxasulfone *fb* post emergence application (metsulfuron + carfentrazone) had the lowest weed index (8% in both the years, respectively) or in other words we can say that reduction in yield in this treatment was lowest because of better weed control efficacy. Weedy check recorded the highest reduction in crop yield ranging to the tune of 30.25%, respectively. These findings align with prior research by Kaur and Singh (2019) and Kumar *et al.* (2022).

Growth parameters: The accumulation of dry matter (Table 2) in wheat was greatly influenced by different crop establishment methods, although statistical significance was not observed. Bed planting with residue exhibited a higher dry matter accumulation per square meter (65.4) in comparison to alternative methods. This can be attributed to the increased available space for the crop, reduced competition from weeds, and enhanced root growth associated with bed planting (Mishra *et al.* 2022, Kaur *et al.* 2023, Sharma *et al.* 2023). Amongst the various weed management options, significantly highest dry matter accumulation (72.6 g/m) was recorded in WFC, followed by W_2 treatment. These two treatments exhibited statistically similar results, and both outperformed the other herbicide options. This superior performance can be attributed to the nearly complete eradication of weeds achieved with pyroxasulfone followed by metsulfuron and carfentrazone in comparison to the other herbicide treatments, leading to less crop-weed competition, more extraction of nutrient and moisture from the soil cause more photosysthesis and resulted in higher dry matter accumulations. These findings are consistent with previous research conducted by Kaur and Singh (2019) and Kumar *et al.* (2021).

Yield parameters: The ear length (cm) and test weight (g) in wheat (Table 2) were notably influenced by various crop

Tables 2 Effect of weed management options and crop establishment methods, growth, yield parameters and yield of wheat

Treatment	Growth parameter			Yield attributes						Yield		
	DMA* (g/m^2)			Ear length (cm)			Test weight (g)			Grain yield (t/ha)		
Year	2021–22	2022–23	Pooled data	2021–22	2022–23	Pooled data	2021–22	2022–23	Pooled data	2021–22	2022–23	Pooled data
Crop establishment methods (C)												
Bed + residue	66.5	64.3	65.4	11.5	11.8	11.7	39.5	40.6	40.1	5.6	5.5	5.6
ZT + residue	63.1	61.1	62.1	11.4	11.5	11.5	39.7	40.3	40.0	5.4	5.2	5.3
CT + residue	63.5	64.6	64.0	11.4	11.4	11.4	39.7	40.4	40.0	5.5	5.4	5.5
SEm±	1.5	1.8	1.2	0.2	0.4	0.2	0.2	0.2	0.2	0.2	0.1	0.1
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management options (W)												
W_1	61.9	59.4	60.7	11.1	11.2	11.2	39.3	40.2	39.8	5.4	5.2	5.3
W_2	68.3	68.1	68.2	12.1	11.9	12.0	40.7	41.3	41.0	5.9	5.7	5.8
W_3	66.5	64.6	65.5	11.6	11.7	11.6	39.6	40.3	39.9	5.5	5.5	5.5
W_4	52.2	52.2	52.2	10.0	10.4	10.2	38.1	39.2	38.7	4.5	4.3	4.4
W_5	72.8	72.3	72.6	12.4	12.6	12.5	40.4	41.7	41.1	6.3	6.2	6.3
SEm±	1.9	2.1	1.4	0.3	0.3	0.2	0.5	0.4	0.3	0.1	0.1	0.1
LSD (P=0.05)	5.4	6.0	4.1	0.8	1.0	0.6	1.4	1.3	1.0	0.4	0.3	0.2

Treatment details are given under Materials and Methods. DMA, Dry matter accumulation; NS, Non significant.

establishment methods, although statistical significance was not achieved. Bed planting with residue recorded longer ear length (11.6 cm) and higher test weight (40.1 g) compared to alternative planting methods. This can be attributed to the improved growth parameters and more efficient allocation of photosynthates to the grain, facilitated by the enhanced growth conditions associated with bed planting (Kaur *et al.* 2020). The additional space provided for the crop, reduced competition from weeds, and enhanced root development contributed to these favourable outcomes (Mishra *et al.* 2022, Sharma *et al.* 2023). Among weed management options, significantly longest ear length (12.5 cm) and highest test weight (41.1 g) were recorded in the weed-free check, closely followed by W_2 treatment. These two treatments exhibited statistically similar results and significantly outperformed the other options. The remarkable performance can be attributed to the nearly complete eradication of weeds achieved with W_2, which promoted more robust growth and subsequently led to the higher yield parameters compared to the other herbicide treatments. These findings align with prior research conducted by Kaur *et al.* (2020) and Kumar *et al.* (2021).

Yield: Pooled data of two year revealed that bed planting resulted in higher wheat yields (5.6 t/ha) compared to other crop establishment systems (ZT and CT) (Table 2), but statistically they are on par with each other's. This increase in yield can be attributed to the reduced competition from weeds in the bed planting method, which allowed for greater growth parameters, ultimately leading to higher yield. Additionally, bed planting with residue or mulching facilitated the efficient utilization of water (Kumar *et al.* 2021) and promoted increased root growth, enabling better nutrient extraction, further contributing to enhanced growth and yield. Among the various weed management options, significantly highest wheat yield (5.8 t/ha) was achieved with pyroxasulfone followed by metsulfuron + carfentrazone, outperforming the other herbicide treatments. In Canada, Johnson *et al.* (2018) observed that the pre-emergence application of pyroxasulfone at a rate of 112 g/ha resulted in the highest grain yield of wheat, reaching 5.47 t/ha. Similarly, in a study conducted in Raipur, Kumar *et al.* (2022) reported that the application of pyroxasulfone (PE) 85% WG at 127.5 g/ha led to higher test weight (41.49 g) greater grain yield (38.39 q/ha), and increased straw yield (44.50 q/ha) compared to the weedy check. These findings are consistent with previous research conducted by Kaur *et al.* (2020), Ghosh *et al.* (2022), Rishi Raj *et al.* (2022), Mishra *et al.* (2022) and Sharma *et al.* (2023).

The interaction effect of crop establishment methods and weed management options didn't show any significant difference in WCE, WI, DMA, test weight and yield. From the present study it can be concluded that *Phalaris minor* poses a significant challenge in wheat fields due to its mimicry with the crop. Bed planting with residue management emerged as the most effective crop establishment method, reducing weed density and enhancing wheat growth parameters. Among herbicide options, pyroxasulfone followed by metsulfuron + carfentrazone demonstrated exceptional weed control efficiency, weed index, matching the weed-free check. This translated to longer ear length, higher test weight, and ultimately, increased wheat yields. Bed planting with residue also led to higher yields, emphasizing its overall superiority. These findings underscore the importance of integrated weed management strategies and specific crop establishment practices for optimal wheat production in the presence of *Phalaris minor*.

REFERENCES

Chaudhary C, Yadav D B, Yadav A, Hooda V and Chaudhary A. 2022. Standardization of spray technique for pre-emergence herbicides in ZT-wheat (*Triticum aestivum*) with surface residue cover. *The Indian Journal of Agricultural Sciences* **92**(11): 1358–63. https://doi.org/10.56093/ijas.v92i11.125029

Das T K. 2018. Using chemical seed dormancy breakers with herbicides for weed management in soybean and wheat. *Weed Research* **58**: 188–99.

Ghosh S, Das T K, Shivay Y S, Bhatia A, Biswas D R, Bandyopadhyay K K, Sudhishri S, Yeasin M, Raj R, Sen S and Rathi N. 2021. Conservation agriculture effects on weed dynamics and maize productivity in maize-wheat-greengram system in north-western Indo-Gangetic Plains of India. *Indian Journal of Weed Science* **53**(3): 244–51.

Ghosh S, Das T, Shivay S and Bandyopadhyay K. 2022. Weed interference and wheat productivity in a conservation agriculture-based maize-wheat-mungbean system. *Journal of Crop and Weed* **18**(1): 111–19.

Gill and Vijaykumar. 1969. Chemical weed control in onion. *Indian Journal of Horticultural Sciences* **29**: 53–58.

Heyne EG. 1987. *Wheat and Wheat Improvement*, 2nd edn. Madison, Wisconsin, USA.

Johnson E N, Wang Z, Geddes C M, Coles K, Hamman B and Beres B L. 2018. Pyroxasulfone is effective for management of Bromus spp. in winter wheat in western Canada. *Weed Technology* **32**(6): 739–48.

Kaur A and Singh S. 2019. Performance of different herbicides on wheat grain yield and correlation between growth and yield attributes of wheat and weeds. *Indian Journal of Weed Sciences* **51**(2): 129–32.

Kaur Ramanjit, Raj R, Das T K, Singh R, Jaidka M and Shekhawat K. 2020. Managing weeds using sequential herbicides in maize for improving crop growth and productivity under irrigated conditions in north-western India. *Maydica* **65** (11): 1–10.

Kaur Ramanjit, Kumar Sunil, Dass Anchal, Singh Teekam, Kumar Praveen and Rakesh Dawar. 2023. Response of maize (*Zea mays*) to different planting methods with limited irrigation at water sensitive growth stages. *The Indian Journal of Agricultural Sciences* **93** (6): 626–31. https://doi.org/10.56093/ijas.v93i6.124163

Kaur T, Bhullar M S and Kaur S. 2019. Control of herbicide resistant *Phalaris minor* by Pyroxasulfone in wheat. *Indian Journal of Weed Science* **51**(2): 123–28.

Kumar A, Pandey D, Patel J R, Agrawal H P, Agrawal N K, Ahmad A, Hetram Rawate D and Mitasha M. 2022. Efficacy of herbicides against diverse weed flora of wheat (*Triticum aestivum* L.). *The Pharma Innovation Journal* SP-**11**(10): 11–15.

Kumar R, Nand V, Verma S K, Doharey R K, Kumari A and Raju. 2021. Effect of herbicides on weed control efficiency (per cent), yield attributes, yield and profitability of wheat (*Triticum* *aestivum* L.). *Journal of Pharmacognosy and Phytochemistry* **8**(2): 118–21.

Mishra J S, Kumar R, Mondal S, Poonia S P, Rao K K, Dubey Rachana, Raman, Rohan Kumar, Dwivedi S K, Kumar Rahul, Saurabh Kirti, Monobrullah Md, Kumar Santosh, Bhatt B P, Malik R K, Kumar Virender and McDonald Andrew. 2022. Tillage and crop establishment effects on weeds and productivity of a rice-wheat-mungbean rotation. *Field Crops Research* **284**: 108577.

Raj R, Das T K, Ghosh A, Govindasamy P, Kumar V, Babu , Saha P, Sen S, Roy A, Sharma T and Tiwari G. 2022. Crop-establishment methods and weed management effects on weeds, wheat (*Triticum aestivum*) yield and economics under a conservation agriculture-based rice (*Oryza sativa*)–wheat system. *Indian Journal of Agronomy* **67**(4): 354–62.

Sharma T, Das T K, Govindasamy P, Raj R, Sen S, Roy A, Kumar J, Gunturi A, Saha P and Tiwari G. 2023. Tillage, residue, and nitrogen management effects on weed interference, wheat growth, yield and nutrient uptake under conservation agriculture-based pigeonpea-wheat system. *Indian Journal of Weed Science* **55**(2): 217–22.

Singh S, Dhaka A K and Hooda V S. 2016. Evaluation of Traxos 5% EC (Pinoxaden + Clodinafop propargyl) against *Phalaris minor* and other grassy weeds in wheat. *Haryana Journal of Agronomy* **31**: 1–8.

Singh S, Malik R K, Balyan R S and Singh S. 1995. Distribution of weed flora in wheat in Haryana. *Indian Journal of Weed Science* **27**(3): 114–21.