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Impact of varying doses and application methods of metribuzin on productivity and profitability of wheat (*Triticum aestivum*) under different tillage systems

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ABSTRACT

Addressing the imperative of aligning food production with the escalating global population necessitates the identification of sustainable land management strategies. In the Indo-Gangetic Plains of India, weed infestation causes a significant threat to wheat (*Triticum aestivum* L.) productivity. To address this concern, a field experiment was conducted during the winter (*rabi*) seasons of 2021–22 and 2022–23 at the research farm of CCS Haryana Agricultural University, Rice Research Station, Kaul, Haryana. The primary objective of this experiment was to assess the effects of varying doses and application methods of metribuzin on the productivity and profitability of wheat crop under zero and conventional tillage systems. Notably, the application of post-emergence (POE) metribuzin at a dose of 350 g/ha as a urea-mix broadcast at 35 days after sowing (DAS) in combination with pinoxaden (PDN) exhibited notable benefits in terms of productivity and economic viability of wheat. This treatment yielded significantly higher number of effective tillers/mrl (111 in zero tillage; 112 in conventional tillage) and grain yield (5,573 kg/ha in zero tillage; 5,972 kg/ha in conventional tillage). Moreover, the treatment combination of metribuzin at 350 g/ha as a urea-mix broadcast and pinoxaden applied at 35 DAS resulted in the highest net returns and benefit-cost ratio under both tillage systems.

Keywords: Conventional tillage, Metribuzin, Pinoxaden, Productivity, Zero tillage

The rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system holds paramount importance in India, but it faces sustainability issues i.e. extensive burning of rice residues, deterioration of soil structure, proliferation of wheat-associated weeds and escalating cultivation costs (Chauhan *et al.* 2012, Chaudhary *et al.* 2019). *Phalaris minor* causes a major problem in rice-wheat system within Indo-Gangetic Plains (Chhokar *et al.* 2012, Chaudhary *et al.* 2022). In R-W cropping system, the persistent application of isoproturon herbicides to manage *Phalaris minor* has led to emergence of resistant biotypes in northwest India (Chhokar *et al.* 2018). Multiple alternative herbicides recommended for the control of *Phalaris minor* have lost their effectiveness due to development of multiple and cross resistance (Brar *et al.* 2002, Kaur *et al.* 2016). Hence, it is imperative to conduct screening and assessment of herbicides for management of *Phalaris minor*. Herbicides, viz. metribuzin and pinoxaden have demonstrated efficacy in managing *P. minor*, along with other grassy and broadleaf weeds (Pandey and Verma 2002, Malik *et al.* 2005, Punia *et al.* 2005, Singh 2015, Yadav *et al.* 2018). Farmers in the northwestern region of India traditionally burn crop residue from rice and wheat fields, which has substantial adverse ecological consequences (Singh *et al.* 2015, Chaudhary *et al.* 2019). However, innovative tools such as happy seeder and rotary disk drill tools enable direct sowing of wheat seeds with either partial or complete rice residue (Sidhu *et al.* 2007). The effectiveness of herbicides, employed under two distinct conditions - zero tillage (ZT) and conventional tillage (CT) - was expected to differ due to the presence of straw, herbicide solubility and weed species. Hence, it becomes crucial to optimize the dose, formulation and application timing of herbicides to ensure efficient weed control in wheat cultivation when rice straw was retained on surface.

The primary objective of this study was to evaluate the efficacy of metribuzin in management of *Phalaris minor* in wheat crop, along with its impact on wheat productivity and economic viability. The evaluation will encompass the examination of different application timings, varied dosages and application methods, with and without rice crop residues.

MATERIALS AND METHODS

Description of field sites and experimental design: A field experiment was conducted at the research farm of CCS Haryana Agricultural University, Rice Research

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Station, Kaul, Haryana, during winter (*rabi*) seasons of 2021–22 and 2022–23 to assess the bio-efficacy of PRE (pre-emergence), EPOE (early post-emergence) and POE (post-emergence) application of herbicides both separately and in combination against the predominant weeds in wheat. The Kaul region experiences a climate characterized by hot and dry summers along with cold winters. Figures 1a and 1b present the agro-meteorological data for the wheat seasons in this region. The soil in both experimental fields exhibited a clay loam texture. It was low in available nitrogen (106 kg/ha), medium in available phosphorous (21 kg/ha) and high in available potassium (360 kg/ha). Additionally, the soil had an alkaline *p*H of 8.65 and EC was 0.52 dS/m. In experiment-I, wheat was seeded under zero-tillage with happy seeder under full residue (8.0 tonnes/ha) situations whereas, in experiment-II, the crop was sown with a seed-cum-fertilizer drill under conventional tillage without any residue retention. Each experimental plot had dimensions of 7.0 × 2.2 m^2 in size. The wheat variety WH 1184 was chosen as the experimental cultivar for sowing during the winter (*rabi*) seasons of 2021–22 and 2022–23. The sowing process utilized a seeding rate of 100 kg/ha, with a row spacing of 20 cm. The recommended basal dose for sowing entails the application of 20 kg of nitrogen (N) and 40 kg of phosphorus (P)/ha. Irrigation was administered in accordance with the crop's water requirements using the flooding method. Pre-emergent herbicides were administered immediately after sowing on adequately moistened soil, while early post-emergence (EPOE) and post-emergence (POE) herbicides were administered at 21 and 35 days after sowing (DAS), respectively. These herbicides were applied using a knapsack sprayer fitted with a flat fan nozzle, with a spray volume of 500 litre/ha. Furthermore, broadcasting treatments employing diverse media such as urea and sand were conducted. The crop was cultivated utilizing conventional agronomic methodologies in accordance with the guidelines provided by the state university. The experiments followed a randomized complete block design (factorial) with a total of 16 herbicide treatments (metribuzin) (MTZ) with and without pinoxaden (PDN) applied at 50 g/ha, each replicated thrice. The treatments included the following: PRE MTZ at 210 and 350 g/ha spray; EPOE (21 DAS) MTZ at 105 g/ha spray and MTZ at 210, 280, and 350 g/ha sand and urea-mix broadcast; and POE (35 DAS) MTZ at 105 g/ha spray and MTZ at 210, 280, and 350 g/ha sand and urea-mix broadcast.

Crop sampling: A total of 5 plants were selected, and their respective spikes were harvested for subsequent analysis. The grains were then carefully separated from the spikes and enumerated. The average number of grains per spike was calculated for each treatment. Average value of no. of effective tillers/mrl were counted from each plot at harvest. Threshing was carried out separately for each plot and the grain yield was evaluated in kg/plot. Grain yield was determined at a moisture content of 14% after threshing with a plot thresher, followed by cleaning. The recorded data were converted into kg/ha. The net returns and benefit-cost ratio for each treatment were calculated to determine their economic feasibility.

Statistical analysis: Before statistical analysis, to increase the homogeneity of the variance, weed data were subjected to square root transformation ($\sqrt{X+1}$). Each dataset underwent separate analysis of variance (ANOVA) for each year to facilitate a comprehensive comprehension of the findings. The ANOVA assumptions were held under square root transformations and back-transformed data are presented in Fig 1a and 1b. The statistical analysis of the data was done by utilizing a software named 'OPSTAT' developed by CCS Haryana Agricultural University, Hisar (Sheoran *et al.* 1998).

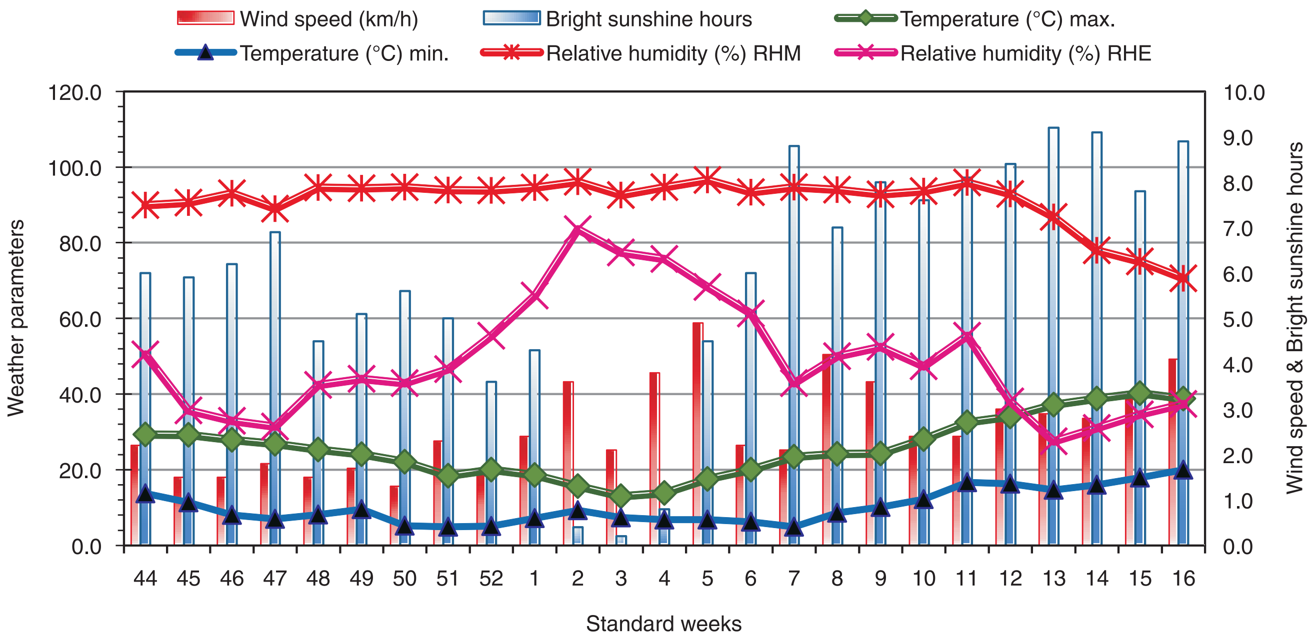

Fig 1a Mean of weekly meteorological data of RRS, Kaul (Kaithal), Haryana for the crop span (November, 2021–April, 2022).

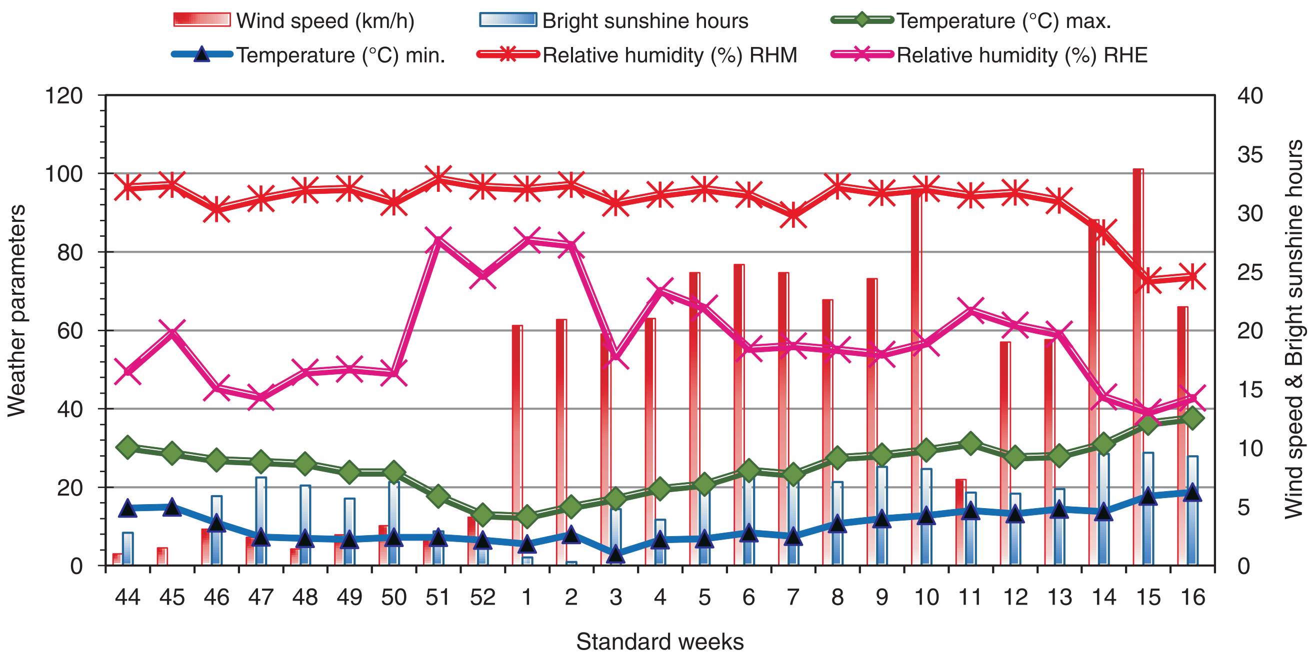

Fig 1b Mean of weekly meteorological data of RRS, Kaul (Kaithal), Haryana for the crop span (November, 2022–April, 2023).

RESULTS AND DISCUSSION

Weed interference: There was 1 monocotyledon grass and 3 dicotyledon weeds in the experimental fields. The predominant weed species of both experimental fields were *P. minor*, *M. denticulata, R. dentatus* and *M. indica* during both years. In comparison to the second year, the total weeds were lower in the first year.

Zero tillage: Conservation tillage practices aims at

Table 1 Effect of metribuzin (MTZ) and pinoxaden (PDN) on effective tillers (no./mrl) and no. of grains per spike of wheat in both zero and conventional tillage during 2021–22 and 2022–23

Treatment	Time of application	Zero tillage						Conventional tillage					
		Effective tillers (no./mrl)			Grains per spike			Effective tillers (no./mrl)			Grains per spike		
		With PDN	Without PDN	Mean	With PDN	Without PDN	Mean	With PDN	Without PDN	Mean	With PDN	Without PDN	Mean
MTZ-210 spray	PRE	73	69	71	32	32	33	73	70	72	34	36	35
MTZ-350 spray		74	72	73	33	34	34	74	72	73	36	38	37
MTZ-105 spray	21 DAS	81	73	77	40	35	38	81	74	77	43	39	41
MTZ-210 sand-mix		82	76	79	42	36	39	82	76	79	44	36	40
MTZ-280 sand-mix		82	77	80	41	36	39	83	77	80	44	37	40
MTZ-350 sand-mix		84	77	81	42	37	40	85	78	81	45	38	42
MTZ-210 urea-mix		85	79	82	43	38	41	86	78	82	46	43	45
MTZ-280 urea-mix		86	80	83	44	39	42	88	80	84	47	44	46
MTZ-350 urea-mix		89	81	85	45	41	43	89	81	85	48	45	47
MTZ-105 spray	35 DAS	92	90	91	45	44	45	90	90	90	49	47	48
MTZ-210 sand-mix		100	92	96	46	45	46	97	91	94	49	48	48
MTZ-280 sand-mix		102	94	98	48	46	47	100	93	96	51	49	50
MTZ-350 sand-mix		104	95	99	47	47	47	102	94	98	50	49	49
MTZ-210 urea-mix		106	97	102	48	47	48	106	95	100	50	50	50
MTZ-280 urea-mix		109	101	105	49	48	49	109	96	102	51	50	51
MTZ-350 urea-mix		111	100	106	50	49	50	112	98	105	52	51	52
Mean		92	85		44	41		91	84		46	44	
CD (P=0.05)		PDN treatments = 1			PDN treatments = 1			PDN treatments = 1			PDN treatments = 1		
		MTZ treatments = 3			MTZ treatments = 3			MTZ treatments = 4			MTZ treatments = 4		
		PDN × MTZ = 5			PDN × MTZ = NS			PDN × MTZ = 5			PDN × MTZ = NS		

minimizing soil disturbance through techniques such as zero tillage, which can result in the retaining the residue on the soil surface hence influencing the temperature and moisture status of soil, potentially impacting weed seed germination and emergence patterns across growing seasons (Singh and Kaur 2012). Broadcasting metribuzin at 350 g/ha along with urea in combination with PDN recorded significantly higher number of effective tillers/mrl (Table 1). Similar findings were reported by Anmol *et al.* (2022) and Soni *et al.* (2023). The cumulative influence of growth and yield attributes ultimately increased the grain yield of wheat. Grains per spike were evaluated under metribuzin 210, 280, and 350 g/ha sand-mix broadcast at 35 DAS and metribuzin 210 and 280 g/ha urea-mix broadcast at 35 DAS. The results indicated that these treatments were statistically similar to metribuzin at 350 g/ha urea-mix broadcast in combination with PDN (50 grains per spike) (Table 1). The application of metribuzin at the post-emergence stage resulted in a higher grain yield in comparison to the same treatment applied at the early post-emergence stage (21 DAS) (Table 2). Minimum grain yield was obtained with PRE metribuzin at 210 g/ha i.e. 4,047 kg/ha, however, it increased with increase in dose to 350 g/ha. Metribuzin at same doses resulted in higher grain yield when applied as urea-mix than sand-mix at both the stages (21 and 35 DAS) of post-emergence application. The application of pinoxaden as a post-emergence herbicide, in combination with various metribuzin treatments, demonstrated a significant enhancement in wheat grain yield (4,975 kg/ha) as compared to no pinoxaden (4,680 kg/ha). The maximum harvest index of 41.9%, was achieved with POE metribuzin at 350 g/ha broadcasted with urea in combination with PDN.

When recommending treatments to farmers, economic viability was an important consideration. The benefit-cost ratio was calculated to evaluate the economics of different weed control treatments used in this experiment. The comparative economics of different weed control treatments revealed that highest net returns and benefit-cost ratio were obtained in case of POE broadcasting of metribuzin 350 g/ha with urea at 35 DAS in combination with PDN (₹54,633/ha and 1.91) (Table 3).

Conventional tillage: Plant growth is a complex interaction between genetic characteristics and environmental conditions, with environmental factors being the ones that can be controlled to some extent to achieve higher yields. Broadcasting of metribuzin at 350 g/ha with urea and PDN recorded significantly higher number of effective tillers/mrl (112) (Table 1). The cumulative influence of growth and yield attributes ultimately increased the grain yield of wheat. The statistical analysis revealed statistically similar outcomes in terms of no. of grains per spike across different treatments of metribuzin, viz. 210, 280, and 350 g/ha when

Table 2 Effect of metribuzin (MTZ) and pinoxaden (PDN) on grain yield (kg/ha) and harvest index (%) of wheat in both zero and conventional tillage during 2021–22 and 2022–23

Treatment	Time of application	Zero tillage						Conventional tillage					
		Grain yield (kg/ha)			Harvest index (%)			Grain yield (kg/ha)			Harvest index (%)		
		With PDN	Without PDN	Mean	With PDN	Without PDN	Mean	With PDN	Without PDN	Mean	With PDN	Without PDN	Mean
MTZ-210 spray	PRE	4,116	4,047	4,082	37.2	36.9	37.0	4,228	4,192	4,210	37.3	37.2	37.2
MTZ-350 spray		4,148	4,105	4,127	37.2	37.1	37.2	4,253	4,220	4,237	37.4	37.3	37.3
MTZ-105 spray	21 DAS	4,610	4,214	4,412	38.9	37.4	38.1	4,777	4,296	4,537	38.9	37.4	38.2
MTZ-210 sand-mix		4,736	4,260	4,498	39.5	37.6	38.6	4,823	4,395	4,609	39.1	37.7	38.4
MTZ-280 sand-mix		4,747	4,333	4,540	39.5	38.0	38.8	4,905	4,428	4,667	39.3	37.8	38.6
MTZ-350 sand-mix		4,826	4,398	4,612	39.7	38.3	39.1	4,957	4,486	4,722	39.4	38.0	38.7
MTZ-210 urea-mix		4,865	4,412	4,639	39.8	38.3	39.1	5,004	4,538	4,771	39.5	38.2	38.9
MTZ-280 urea-mix		4,897	4,466	4,682	39.9	38.5	39.2	5,067	4,566	4,817	39.6	38.3	38.9
MTZ-350 urea-mix		4,938	4,550	4,744	40.1	38.9	39.5	5,115	4,707	4,911	39.7	38.6	39.1
MTZ-105 spray	35 DAS	5,039	5,012	5,026	40.2	40.1	40.1	5,236	5,191	5,214	40.0	39.9	40.0
MTZ-210 sand-mix		5,325	5,070	5,198	40.9	40.2	40.6	5,619	5,288	5,454	41.3	40.2	40.8
MTZ-280 sand-mix		5,347	5,139	5,243	41.0	40.4	40.7	5,668	5,327	5,498	41.5	40.4	41.0
MTZ-350 sand-mix		5,430	5,163	5,297	41.4	40.5	41.0	5,762	5,398	5,580	41.8	40.6	41.2
MTZ-210 urea-mix		5,474	5,210	5,342	41.5	40.7	41.1	5,822	5,444	5,633	42.0	40.7	41.4
MTZ-280 urea-mix		5,535	5,239	5,387	41.8	40.8	41.3	5,899	5,506	5,703	42.4	41.0	41.7
MTZ-350 urea-mix		5,573	5,263	5,418	41.9	40.8	41.4	5,972	5,544	5,758	42.5	41.1	41.8
Mean		4,975	4,680		40.0	39.0		5,194	4,845		40.1	39.1	
CD (P=0.05)		PDN treatments = 48 MTZ treatments = 129 PDN × MTZ = 181			PDN treatments = 0.7 MTZ treatments = 2.1 PDN × MTZ = NS			PDN treatments = 45 MTZ treatments = 123 PDN × MTZ = 178			PDN treatments = 0.8 MTZ treatments = 2.3 PDN × MTZ = NS		

Table 3 Effect of metribuzin (MTZ) and pinoxaden (PDN) on net returns (₹/ha) and B:C ratio of wheat in both zero and conventional tillage during 2021–22 and 2022–23

Treatment	Time of application	Zero tillage				Conventional tillage			
		Net returns (₹/ha)		B:C ratio		Net returns (₹/ha)		B:C ratio	
		With PDN	Without PDN	With PDN	Without PDN	With PDN	Without PDN	With PDN	Without PDN
MTZ-210 spray	PRE	24,966	25,795	1.42	1.45	22,562	24,067	1.35	1.39
MTZ-350 spray		25,142	26,488	1.43	1.46	22,587	24,147	1.36	1.40
MTZ-105 spray	21 DAS	35,574	29,675	1.60	1.52	34,302	26,595	1.54	1.43
MTZ-210 sand-mix		37,800	30,204	1.64	1.53	34,872	28,276	1.54	1.46
MTZ-280 sand-mix		37,792	31,465	1.63	1.55	36,333	28,696	1.56	1.46
MTZ-350 sand-mix		39,163	32,568	1.65	1.56	37,159	29,660	1.57	1.48
MTZ-210 urea-mix		40,485	33,343	1.68	1.58	38,626	31,222	1.60	1.50
MTZ-280 urea-mix		40,890	34,149	1.57	1.59	39,687	31,566	1.61	1.51
MTZ-350 urea-mix		41,489	35,714	1.69	1.62	40,430	34,228	1.62	1.55
MTZ-105 spray	35 DAS	44,447	46,138	1.75	1.81	43,810	45,129	1.69	1.73
MTZ-210 sand-mix		49,992	46,964	1.84	1.81	51,349	46,748	1.80	1.75
MTZ-280 sand-mix		50,198	48,156	1.84	1.83	52,114	47,312	1.81	1.76
MTZ-350 sand-mix		51,673	48,403	1.86	1.83	53,823	48,539	1.83	1.77
MTZ-210 urea-mix		53,077	49,862	1.89	1.86	55,565	49,991	1.86	1.80
MTZ-280 urea-mix		54,090	50,226	1.90	1.87	56,895	51,024	1.88	1.82
MTZ-350 urea-mix		54,633	50,473	1.91	1.87	58,170	51,547	1.90	1.82

administered as sand-mix broadcast 35 DAS. Similarly, when metribuzin was applied as a urea-mix broadcast at 35 DAS, the treatments at 210 and 280 g/ha exhibited comparable results. These results were also comparable to the application of metribuzin at 350 g/ha with urea in combination with pinoxaden (PDN), which resulted in an average of 52 grains per spike. Notably, the grain yield of wheat displayed a progressive increase with higher doses of metribuzin ranging from 210 to 350 g/ha during both the years of study.

Furthermore, when metribuzin was administered as a post-emergence treatment at 35 DAS, it resulted in higher grain yield in comparison to the identical treatment performed as an early post-emergence application at 21 DAS. The pre-emergence application of metribuzin at a dosage of 210 g/ha exhibited the lowest grain yield of 5,972 kg/ha, but the yield improved when a higher dosage of 350 g/ha was used. Additionally, the incorporation of pinoxaden as a post-emergence herbicide, in conjunction with metribuzin applications, led to a notable enhancement in the wheat's grain yield (5,194 kg/ha) compared to treatments without pinoxaden (4,845 kg/ha). The maximum grain yield was observed with POE application of metribuzin at 350 g/ha with urea at 35 DAS and PDN (5,972 kg/ha), while the lowest yield was recorded with metribuzin at 210 g/ha as a pre-emergence spray without PDN (4,192 kg/ha). Reduction in crop-weed competition under this treatment could have saved a substantial amount of nutrients for the crop, which led to accelerated growth, enabling it to utilize more soil moisture and nutrients. All these favourable effects resulted in significant increase in various yield-determining characters of wheat by improving the source-sink relationship. Similar results were observed by Anmol *et al.* (2022) and Soni *et al.* (2023). The maximum harvest index of 42.5% was achieved with metribuzin 350 g/ha broadcasted with urea at 35 DAS in combination with PDN (Table 2). The treatment combination of metribuzin at 350 g/ha urea-mix broadcast and pinoxaden applied at 35 DAS resulted in highest net returns (₹58,170/ha), as well as benefit:cost (B:C) ratio (1.90) during both the years (Table 3).

The findings of this study suggest that the application of post-emergence (POE) metribuzin at a dosage of 350 g/ha, combined with urea at 35 DAS, along with pinoxaden exerted a positive influence on the productivity and profitability of wheat. Consistently, the application of increasing doses of metribuzin resulted in a significant increase in wheat grain yield, ranging from 210 to 350 g/ha, as observed during the two-year study. The significance of timely application should be emphasized, as it plays a crucial role in effectively controlling both grassy and broad-leaf weeds, optimizing the herbicide's efficacy, and ultimately enhancing productivity in agricultural fields. Therefore, it can be safely propounded that POE metribuzin at 350 g/ha urea-mix + pinoxaden 50 g/ha at 35 DAS as broadcast can be used to effectively manage the dominant and complex weed flora currently infesting the wheat crop in R-W cropping system of Haryana.

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