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Efficacy of Pyroxasulfone against Weeds and their Impact on Yield and Economic Analysis of Wheat

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Abstract

A field experiment was conducted during the *rabi* season (November, 2021–April, 2022) at AICRP on Wheat, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India to evaluate the efficacy of Pyroxasulfone in wheat cultivation to enhance crop productivity and profitability. The study assessed eight weed management treatments, including herbicide applications (pendimethalin at 1000 g ha^{-1}; pyroxasulfone at 127.5 g ha^{-1}; pendimethalin+pyroxasulfone at 1250+127.5 g ha^{-1}; metribuzin at 300 g ha^{-1}; pendimethalin+metribuzin at 1250+280 g ha^{-1}; pyroxasulfone+metribuzin at 127.5+280 g ha^{-1} as pre-emergence), hand weeding once at 25 DAS and weedy check, in a randomized block design with three replications. The experimental field was dominated by *Phalaris minor* (17.82%) among monocot weeds, while *Medicago denticulata* (28.97%), *Cichorium intybus* (26.19%), *Chenopodium album* (16.10%), and *Anagallis arvensis* (10.92%) among the dicot weeds throughout the crop growing period. Results revealed a substantial decrease in weed density and dry weight across all treatments, with the combination of pyroxasulfone+metribuzin at 127.5+280 g ha^{-1} showing superior efficacy. Weed control efficiency was highest with hand weeding, followed by herbicide treatments. Additionally, treatments significantly influenced wheat growth parameters and yield attributes, with the application of pyroxasulfone+metribuzin at 127.5+280 g ha^{-1} resulting in the tallest plants and highest number of tillers square^{-1} meter. Grain yield was also found significantly higher in plots treated with pyroxasulfone+metribuzin at 127.5+280 g ha^{-1}. The economic analysis demonstrated that pyroxasulfone+metribuzin at 127.5+280 g ha^{-1} yielded the highest net monetary returns, indicating its economic viability.

Keywords: Hand weeding, pyroxasulfone+metribuzin, weed management, wheat

1. Introduction

Wheat (*Triticum aestivum* L.) stands as a pivotal *rabi* cereal crop significantly impacting India's economy (Jitendra et al., 2022; Parewa et al., 2019). It holds primacy as the most extensively consumed grain, serving as a cornerstone for food and nutritional security within the nation (Sirazuddin et al., 2024). It serves as a principal source of both carbohydrates and proteins for humans and animals alike, boasting a composition rich in starch (60–90%), protein (11–16.5%), fat (1.5%), inorganic ions (1.2%) and essential vitamins such as B-complex and vitamin-E (Nirala et al., 2022; Yadav et al., 2023). Globally, wheat cultivation spans 223.40 mha, yielding 778.6 million mt. Within India, cultivation encompasses 31.62 mha, yielding an average of 3420 kg ha^{-1} and a cumulative production of 109.2 million mt (Anonymous, 2021). Notably, in Madhya Pradesh, wheat cultivation extends over 10.02 mha, yielding 16.52 million mt with productivity of 3298 kg ha^{-1} (Anonymous, 2021). The expansion of irrigation facilities through the implementation of new projects, increased fertilizer application and the adoption of modern crop production techniques have all led to comparable increases in yield (Verma et al., 2024; Patidar et al., 2018). However, the cultivation of dwarf wheat varieties, which advocate for closer spacing, presents challenges for mechanical weeding (Swati et al., 2023; Sairam et al., 2023). Additionally, a shortage of labor exacerbates the issue, allowing weeds to grow to heights that impede physical management, particularly during periods of peak demand (Pahade et al., 2023; Verma et al., 2023). Similarly, the introduction of diverse cropping methods has reduced the time available for initial tillage in irrigated wheat fields, resulting in increased weed problems (Tomar et al., 2023; Jha et al., 2013). Various factors influence wheat production, with intense weed competition being a significant contributor to decreased crop yields (Patel et al., 2023; Kumhar et al., 2022). Research indicates that weed interference can cause a notable reduction in yield, with the critical period for crop-weed competition typically occurring within the first 30 days after sowing (Verma et al., 2023; Kumar et al., 2023). During this time, the highest weed density is observed. Losses attributed to weed competition prevail over those caused by insects and diseases combined (Toppo et al., 2023; Verma et al., 2023). Furthermore, weeds can facilitate the spread of diseases, offer shelter to pests and serve as alternative hosts, exacerbating agricultural challenges (Jha et al., 2011; Porwal et al., 2024).

Weed management has emerged as a crucial aspect of maximizing crop yield (Sairam et al., 2023). Manual weeding or using animal-drawn equipment is not only inefficient but also incurs significant costs due to rising labor and fuel expenses (Verma et al., 2022). In such scenarios, the most viable and cost-effective approach to weed control is the judicious application of herbicides (Tomar et al., 2023). Therefore, it is imperative to explore economical and efficient weed control strategies to address weed issues in wheat cultivation. While several herbicides like Sulfosulfuron, Metribuzin and Metsulfuron are commonly utilized in wheat fields, they may not effectively target all weed varieties. Thus, there is a need to assess alternative herbicides for more successful weed management in wheat crops. To enhance weed control efficacy while reducing application costs, the utilization of pre-emergence herbicides and pre-mixtures has emerged as a viable alternative. Applying pre-emergence herbicides into the soil rather than directly onto crop plants can minimize or prevent phytotoxic effects (Khalil et al., 2019). This approach also helps in mitigating herbicide resistance (Chaudhari et al., 2017). Henceforth, this research was conducted to effectively manage weeds with pre-emergence herbicides and boost wheat crop yield.

2. Materials and Methods

A field experiment was conducted during the *rabi* season (November, 2021–April, 2022) at the AICRP on wheat and barley, Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India (23°09′ N, 79°58′ E and 411.78 meters above mean sea level). The average weekly maximum temperature was 21 to 38.4 degrees Celsius, while the average weekly minimum temperature was 4.8 to 18.2 degrees Celsius, with relative humidity ranging from 68 to 93% in the morning and 13 to 69% in the evening. A total of 53.3 mm of winter rainfall was recorded during the crop growth period. The soil of the experimental field was clay in texture. It had a low level of organic carbon (0.61%), available nitrogen (371 kg ha^{-1}) and available phosphorus (17.1 kg ha^{-1}), but a high level of accessible potassium (296 kg ha^{-1}). The soil was practically neutral in response (7.1 pH) and the soluble salt content (0.32 ds m^{-1}) was below the hazardous limit. The treatments were arranged in a randomized block design with eight treatments and three replications. Eight treatments consisted of various weed management practices, i.e. pendimethalin at 1000 g ha^{-1}; pyroxasulfone at 127.5 g ha^{-1}; pendimethalin+pyroxasulfone at 1250+127.5 g ha^{-1}; metribuzin at 300 g ha^{-1}; pendimethalin+metribuzin at 1250+280 g ha^{-1}; pyroxasulfone+metribuzin at 127.5+280 g ha^{-1} as pre-emergence (3 DAS); hand weeding once at 25 DAS and weedy check. All the herbicides are applied as pre-emergence (PE) applications. The wheat seed was used at 100 kg ha^{-1} with a uniform distance of 20 cm between rows. The crop received a prescribed fertiliser dosage of 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} through urea, single super phosphate and murate of potash, respectively. Regardless of the herbicide dosage, it was applied as a pre-emergence treatment 3 days after sowing (DAS) of wheat. Before application, the prescribed amount of herbicide and water for each plot were thoroughly mixed. The herbicides were then applied to the plots using a backpack sprayer fitted with a flat fan nozzle. A fresh solution was prepared for each plot individually on every spray. After application, observations were made on weed presence at 40 DAS. Statistical analysis was conducted using the analysis of variance (ANOVA) method in standard statistical software and treatment means were compared at a 5% level of significance using critical differences (CD). Weed control efficiency (WCE) was calculated as a percentage using a formula

WCE=(DMC-DMT)×100

Where, DMC is the dry matter of weeds in the control (unweeded) plot; DMT is the dry matter of weeds in the treated plot.

3. Results and Discussion

3.1. Weed flora

The experimental area was completely infested with a diverse range of weeds, comprising both dicots and monocots. Among the total weed population, dicotyledonous weeds were more prevalent, accounting for 82.18%, compared to monocotyledonous weeds, which constituted 17.82%. The primary monocot weed observed in the experimental plot was *Phalaris minor*, representing 17.82% of the monocot weed population. In contrast, the most common dicot weeds included *Medicago denticulata* (28.97%), *Cichorium intybus* (26.19%), *Chenopodium album* (16.10%), and *Anagallis arvensis* (10.92%). Raghav et al., 2023 and Bhalse et al., 2023 also observed the almost similar weed flora in their experimental research. The weed flora under dicots includes species like Medicago denticulata, Cichorium intybus, Chenopodium album and Anagallis arvensis, whereas Phalaris minor was only grassy weed under monocot.

3.2. Density of weeds

Analysis of the data revealed a substantial decrease in weed density across all weed control treatments at 40 days after sowing (DAS) (Table 1). Specifically, the application of various herbicides led to a reduction in the density of the grassy weed *Phalaris minor*. Notably, the combination of pyroxasulfone+metribuzin at 127.5+280 g ha^{-1} demonstrated

Table 1: Effect of weed control treatments on weed density in wheat at 40 DAS

Treatments	Weed density (no. m^{-2})				
	Phalaris minor	*Medicago denticulata*	*Cichorium intybus*	*Chenopodium album*	*Anagallis arvensis*
Pendimethalin at 1000 g ha^{-1}	4.22 (17.35)	3.32 (10.56)	3.38 (10.94)	2.84 (7.59)	2.19 (4.30)
Pyroxasulfone at 127.5 g ha^{-1}	2.37 (5.11)	2.90 (7.95)	3.07 (8.91)	2.55 (6.03)	2.07 (3.80)
Pendimethalin+pyroxasulfone at 1250+127.5 g ha^{-1}	1.73 (2.48)	2.35 (5.03)	2.30 (4.77)	2.35 (5.03)	1.91 (3.17)
Metribuzin at 300 g ha^{-1}	2.77 (7.16)	3.69 (13.09)	3.55 (12.08)	2.90 (7.92)	2.25 (4.57)
Pendimethalin+metribuzin at 1250+280 g ha^{-1}	1.78 (2.68)	2.46 (5.55)	2.39 (5.20)	2.27 (4.66)	2.00 (3.50)
Pyroxasulfone+metribuzin at 127.5+280 g ha^{-1}	1.56 (1.96)	2.17 (4.21)	2.12 (4.02)	2.03 (3.67)	1.76 (2.60)
Weedy check	4.65 (21.12)	5.89 (34.14)	5.58 (30.71)	4.40 (18.88)	3.55 (12.13)
Hand weeding (25 DAS)	1.38 (1.42)	1.49 (1.72)	1.74 (2.53)	1.57 (1.98)	1.30 (1.20)
SEm±	0.05	0.04	0.05	0.07	0.04
CD (p=0.05)	0.15	0.13	0.16	0.22	0.12

Original data given in parenthesis was subjected to square root transformation (√x+1)

the most significant reduction in Phalaris minor density compared to other treatments. Additionally, all weed control treatments effectively reduced the density of broad-leaved weeds, including *Medicago denticulata*, *Cichorium intybus, Chenopodium album*, and *Anagallis arvensis*. However, the combination of pyroxasulfone+metribuzin at 127.5+280 g ha^{-1} exhibited superior efficacy in reducing weed density compared to other treatments, followed by pendimethalin+pyroxasulfone at 1250+127.5 g ha^{-1} and pendimethalin+metribuzin at 1250+280 g ha^{-1}. The tank mixture of pyroxasulfone and metribuzin at a rate of 127.5+280 g ha^{-1} achieved broad-spectrum weed control, effectively managing both monocot and dicot species, and outperformed other herbicidal treatments. Pyroxasulfone works by inhibiting the biosynthesis of long-chain fatty acids and lipids, disrupting the cuticular wax, which increases the plant's vulnerability to desiccation and heat injury. This inhibition also affects protein and gibberellin biosynthesis and disrupts photosynthesis, ultimately leading to plant death. Metribuzin impacts the photosystem-2 complex, blocking electron transport, which halts CO_2 fixation and the production of ATP and $NADPH_2$, thereby arresting plant growth and causing plant death. Notably, hand weeding outperformed all other weed control methods, likely due to the comprehensive removal of diverse weed species. The highest weed population was observed in plots with no weed control measures (Lamani et al., 2024; Kaur et al., 2019).

3.3. *Dry weight of weeds*

Similarly, significant differences in weed dry weight were observed among treatments at 40 DAS (Table 2). Hand weeding resulted in the lowest dry weight of both grassy and broad-leaved weeds compared to other treatments. This outcome can be attributed to the broad-spectrum control of weeds, allowing less space for weed development and facilitating better competition from the wheat crop for resources such as light, nutrients, and space (Atnafu, 2019). Among pre-emergence herbicide-treated plots, the lowest dry weight of both narrow and broad weeds was observed with the application of pyroxasulfone+metribuzin at 127.5+280 g ha^{-1}, followed by pendimethalin+pyroxasulfone at 1250+127.5 g ha^{-1}. The reduced weed biomass can be attributed to the lower weed population under these treatments, indicative of effective weed control (Chhokar and Sharma, 2023). Conversely, plots with uncontrolled weed growth (weedy check) recorded the highest dry weight of weeds, likely due to favorable conditions for weed proliferation, resulting in increased accumulation of dry matter (Jabran et al., 2017).

3.4. *Weed control efficiency*

The range of weed control efficiency across these practices varied from 51.79% to 92.64%. Notably, the highest level of weed control efficiency was achieved through hand weeding, followed by the treatment involving pyroxasulfone+metribuzin at 127.5+280 g ha^{-1}, and pendimethalin+pyroxasulfone at

Table 2: Effect of weed control treatments on weed dry weight in wheat at 40 DAS

Treatments	Weed dry weight (g m^{-2})					WCE (%)
	Phalaris minor	*Medicago denticulata*	*Cichorium intybus*	*Chenopodium album*	*Anagallis arvensis*	
Pendimethalin at 1000 g ha^{-1}	5.04 (24.86)	3.70 (13.20)	3.56 (12.18)	3.13 (9.27)	3.33 (10.56)	51.79
Pyroxasulfone at 127.5 g ha^{-1}	3.26 (10.15)	3.28 (10.29)	3.21 (9.80)	3.06 (8.87)	2.61 (6.30)	69.31
Pendimethalin+pyroxasulfone at 1250+127.5 g ha^{-1}	2.40 (5.29)	2.31 (4.82)	2.45 (5.52)	2.26 (4.59)	2.31 (4.85)	82.67
Metribuzin at 300 g ha^{-1}	3.58 (12.34)	3.84 (14.26)	3.69 (13.11)	3.44 (11.30)	3.45 (11.39)	57.28
Pendimethalin+metribuzin at 1250+280 g ha^{-1}	2.54 (5.95)	2.38 (5.28)	2.53 (5.94)	2.37 (5.12)	2.33 (4.95)	81.23
Pyroxasulfone+metribuzin at 127.5+280 g ha^{-1}	2.14 (4.08)	2.01 (3.56)	2.17 (4.21)	2.01 (3.55)	2.13 (4.08)	86.43
Weedy check	5.36 (28.20)	6.12 (36.94)	6.00 (35.46)	5.21 (26.65)	4.74 (21.99)	0.00
Hand weeding (25 DAS)	1.77 (2.65)	1.42 (1.51)	1.90 (3.11)	1.36 (1.35)	1.61 (2.09)	92.64
SEm±	0.06	0.08	0.06	0.06	0.05	-
CD (p=0.05)	0.18	0.25	0.18	0.17	0.16	-

Original data given in parenthesis was subjected to square root transformation (√x+1)

1250+127.5 g ha^{-1}. Conversely, the weedy check plot exhibited the lowest weed control efficiency. These findings are consistent with prior research (Tiwari et al., 2011a).

3.5. Effect on crop

The impact of various weed management treatments on wheat growth parameters and yield attributes was significant, as evidenced in Table 3. Notably, the highest plant height (85.75 cm) was observed in plots subjected to hand weeding treatment, followed by those treated with pyroxasulfone+metribuzin at 127.5+280 g ha^{-1}, and pendimethalin+pyroxasulfone at 1250+127.5 g ha^{-1}. Conversely, plots designated as weedy exhibited plants of short height, reflecting the absence of herbicidal or mechanical weed control measures (74.45 cm).

The crop dry weight (g m^{-2}) exhibited notable variations according to the herbicidal treatment applied (Table 3). Across all herbicidal treatments, a significantly higher crop dry weight were observed compared to weedy control plots. Specifically, the application of pyroxasulfone+metribuzin at 127.5+280 g ha^{-1} resulted in the higher crop dry weight (815.35 g m^{-2}), followed by pendimethalin+pyroxasulfone at 1250+127.5 g ha^{-1}. However, hand weeding treatment yielded the maximum crop dry weight (830.43 g m^{-2}). These treatments provided superior control of the respective weeds, creating an almost weed-free environment during the critical period of crop-weed competition. This resulted in proper growth and development of the crop plants and ultimately produced a higher crop dry weight.

Yield attributes and wheat yield followed a similar trend to growth attributes under various pre-emergence herbicide doses (Table 3). Nevertheless, hand weeding treatment resulted in the significantly highest number of effective tillers square^{-1} meter (401 m^{-2}) and Grains ear head^{-1} (55). Among herbicidal treatments, pyroxasulfone+metribuzin at 127.5+280 g ha^{-1} yielded the highest number of effective tillers square meter^{-1} (389 m^{-2}) and Grains ear head^{-1} (51), comparable to pendimethalin+pyroxasulfone at 1250+127.5 g ha^{-1}. However, weedy check plots yielded the minimum number of effective tillers square^{-1} meter (245 m^{-2}) and Grains ear head^{-1} (33).

Grain yield exhibited significant variation due to weed control treatments (Table 3). Minimal grain yield was recorded in weedy check plots, where weeds proliferated unchecked throughout the crop season. Conversely, plots subjected to chemical or mechanical weed management displayed considerable differences in grain production. All pre-emergence herbicidal treatments yielded significantly higher grain yields than weedy control plots. Notably, pyroxasulfone+metribuzin at 127.5+280 g ha^{-1} resulted in the highest grain yield (5658 kg ha^{-1}), surpassing all other herbicidal treatments, followed by pendimethalin+pyroxasulfone at 1250+127.5 g ha^{-1}. These treatments significantly reduced

Table 3: Effect of weed control treatments on growth parameter, yield attributes, grain yield and economics in wheat

Treatments	Plant height (cm)	Crop dry weight ($g\ m^{-2}$)	Effective tillers m^{-2}	Grains ear $head^{-1}$	Grain yield (kg ha^{-1})	B:C Ratio
	90 DAS	90 DAS				
Pendimethalin at 1000 g ha^{-1}	77.34	778.12	362	40	4836	2.67
Pyroxasulfone at 127.5 g ha^{-1}	77.72	787.48	370	43	5010	2.57
Pendimethalin+pyroxasulfone at 1250+127.5 g ha^{-1}	80.43	801.49	380	47	5620	2.72
Metribuzin at 300 g ha^{-1}	75.54	765.29	357	39	4589	2.58
Pendimethalin+metribuzin at 1250+280 g ha^{-1}	78.18	795.46	379	45	5050	2.69
Pyroxasulfone+metribuzin at 127.5+280 g ha^{-1}	83.06	815.35	389	51	5658	2.80
Weedy check	74.45	624.77	245	33	2803	1.74
Hand weeding (25 DAS)	85.75	830.43	401	55	5721	2.64
SEm±	0.82	3.53	2.67	0.96	52.9	-
CD (p=0.05)	2.48	10.71	8.11	2.92	160.6	-

Original data given in parenthesis was subjected to square root transformation (√x+1)

the density and dry weight of all weeds, maximizing the availability of nutrients, moisture, aeration, light, and space. This improvement in resource availability enhanced the growth and development of the crop, leading to better yield attributes and consequently, the highest grain and straw yield. However, hand weeding treatment yielded the highest grain yield (5721 kg ha^{-1}) among all weed control methods, consistent with prior research findings (Tiwari et al., 2011; Bari et al., 2020).

3.6. Economics

Economic analysis of the treatments, conducted through input-output analysis, revealed distinct patterns (Table 3). The highest benefit cost ratio were associated with pyroxasulfone+metribuzin at 127.5+280 g ha^{-1} treatment (2.80), followed by Pendimethalin+pyroxasulfone at 1250+127.5 g ha^{-1} (2.72), while the lowest benefit cost ratio were recorded with the weedy check treatment (1.74). These findings align with the (Samota et al., 2024; Sharma and Solanki, 2020).

4. Conclusion

The application of pyroxasulfone+metribuzin at 127.5+280 g ha^{-1} as a pre-emergence strategy emerged as the optimal weed management approach for wheat cultivation.

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