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RESEARCH ARTICLE

Bixlozone + metribuzin (pre-mix) - a recent herbicide combination for managing herbicide resistant *Phalaris minor* and other weeds in wheat in North-West India

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ABSTRACT

The assessment of the efficacy of premix herbicides that combine two different modes of action is crucial for achieving effective and broad-spectrum weed management in wheat, in view of the growing concern over development of herbicide resistance by weeds. A field experiment was conducted for two-years during *Rabi* 2021-22 and 2022-23, at Punjab Agricultural University, Ludhiana, India using a randomized complete block design with three replicates. The objective of the study was to assess the efficacy of pre-mix herbicide combination of bixlozone 50% + metribuzin 10% WG (bixlozone + metribuzin) on herbicide resistant *Phalaris minor* and other weeds in wheat. The pre-mix of bixlozone + metribuzin at 600-750 g/ha with safener cloquintocet at 1000 mL/ha applied at one day before first irrigation [28-30 days after seeding (DAS)] recorded a reduction of 93.5-97.6% and 95.5-98.7% of *P. minor*, 100% of *M. denticulata* and 62.2-100% and 100% of *R. dentatus* biomass at 60 days after application (DAA) in 2021-22 and 2022-23, respectively. Moreover, this herbicide combination improved wheat grain yield by 24.4-22.1% in 2021-22 and 29.4-26.7% in 2022-23 compared to the weedy check. Thus, bixlozone + metribuzin (pre-mix) at 600-750 g/ha with safener cloquintocet at 1000 mL/ha applied at one day before first irrigation (28-30 DAS) provided effective control of diverse weed flora including herbicide resistant *Phalaris minor* and significantly improved the productivity of wheat in Punjab.

Keywords: Bixlozone, Bixlozone + metribuzin, Herbicide resistance, Metribuzin, *Phalaris minor*, Weed management

INTRODUCTION

With the increasing world population, the demand for food is rising and enhancing crop productivity has become more critical than ever (Saha *et al.* 2024). Weeds remain among the most persistent and damaging constraints in agricultural fields, posing a serious challenge to crop establishment and productivity (Rao 2022, Zhou *et al.* 2025). Their interference significantly hampers plant growth and yield potential (Paul *et al.* 2025). In north-west India, poor weed control has been a major factor responsible for the considerable gap between potential and actual wheat yields (Soni *et al.* 2023). On an average, insufficient weed management is estimated to cause around 35% yield losses in wheat annually (Bekele *et al.* 2006). Herbicide usage has played a significant role in boosting crop productivity in agricultural systems (Costa *et al.* 2025). Nevertheless, excessive reliance on herbicides has led to several issues that warrant serious attention (Feng *et al.* 2025). The prolonged and repeated application of herbicides belonging to the same chemical class in these areas has led to the emergence of herbicide-resistant biotypes (Chhokar *et al.* 2025).

A total of 83 weeds in wheat fields has evolved resistance to at least one herbicide (Kumar *et al.* 2023). These resistant weeds have evolved against 21 of the 31 recognized sites of action for herbicides (Singh *et al.* 2021). In India, herbicide resistance in *Phalaris minor* Retz. has emerged as a serious sustainability challenge, threatening the rice-wheat cropping system (RWCS) in the north-western Indo-Gangetic Plains (IGP) (Singh *et al.* 2021). Apart from its resemblance to wheat in early growth stages, its early seed shedding (before crop harvest), non-synchronous maturity, and ability to germinate in multiple flushes makes it particularly troublesome to control (Rana and Rana 2015). Farmers initially relied on isoproturon in the 1980s for its control. However, prolonged dependence on this single herbicide, coupled with monocropping, led to the evolution of isoproturon resistant *P. minor* by 1992-93, marking the first recorded herbicide resistant weed report in

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India (Malik and Singh 1995). By 1993, herbicide resistant *P. minor* had spread to around 0.8-1.0 mha in NW-India, with Haryana being the most affected state (0.56-0.6 mha), followed by Punjab (0.3 mha) (Franke 2002).

To address *P. minor* resistance, other alternative herbicides such as sulfosulfuron, clodinafop, fenoxaprop were recommended (Yadav and Malik 2005). However, within 10-15 years, the efficacy of alternative herbicides too declined, prompting farmers to increase application rates and/or resort to repeated sprays to achieve satisfactory weed control (Bhullar *et al.* 2014). *P. minor* has developed multiple herbicides resistance against different modes of action (Singh 2007, Chhokar and Sharma 2008, Punia *et al.* 2017), such as isoproturon (Singh *et al.* 1998), fenoxaprop-p-ethyl (Abbas *et al.* 2016). Several researchers have undertaken field surveys to examine herbicide usage patterns and spray techniques against resistant *P. minor*, but these efforts have largely been random and yielded inconclusive results (Bhullar *et al.* 2014).

Thus, there is an immediate necessity to introduce herbicides with modes of action distinct from currently used herbicides for managing herbicides resistant *P. minor*. Additionally, the use of herbicide mixtures, either as tank mixes or premixes combining two different mechanisms of action, can help prevent or slow down the development of resistance in weed populations. The deployment of broad-spectrum herbicides would also aid in tackling the challenge posed by diverse weed flora. The new formulation, bixlozone 50% + metribuzin 10% WG (bixlozone + metribuzin), fits this requirement, offering a novel mode of action along with broad-spectrum weed control. Bixlozone, a recently developed oxazole-based herbicide, inhibits the enzyme 1-deoxy-D-xylulose-5-phosphate synthase (DOXP), which disrupts the isoprenoid production at an early stage of the methylerythritol phosphate pathway, thereby providing effective control over both grass and broadleaf weeds (Goggin *et al.* 2025). It also has low volatility and unintended impacts on non-target plants. The second component, metribuzin, an effective post-emergence triazine group herbicide with the mode of action of photosynthesis inhibition is often applied to restrict the broadleaved and annual grass weeds in wheat (Javaid *et al.* 2022). In this context, a field experiment was carried out to determine the efficacy of two-way premix herbicide, combining DOXP and PSII inhibition, under subtropical conditions in India. This study was aimed to evaluate the efficacy and identify effective application rates of the bixlozone + metribuzin (pre-mix) for managing herbicide resistant *P. minor* and other associated weeds in wheat.

MATERIAL AND METHODS

During the *Rabi* seasons of 2021-22 and 2022-23, a field experiment was conducted at the Research Farm, Department of Agronomy, Punjab Agricultural University (PAU), Ludhiana, Punjab, India. It is situated in the northwestern Indo-Gangetic Plains within a subtropical climatic zone. This region is characterized by a semi-arid, subtropical climate, featuring hot, dry summers followed by a humid monsoon period. The winter season starts mildly and becomes colder in December to January. The area typically receives 500 to 750 mm of rainfall annually, with nearly 75% of it occurring during the southwest monsoon. The soil at the test site is loamy sand in texture, with a neutral pH (7.1) and low electrical conductivity (0.14 dS/m). The organic carbon content is low (0.36%), while the soil is low in $KMnO_4$-N (219.4 kg/ha), high in Olsen P (31.2 kg/ha) and high in NH_4OAc-K (361 kg/ha).

The treatments in the field experiment consisted of bixlozone + metribuzin at 500+100, 625+125, 750+150 g/ha with safener cloquintocet at 1000 mL/ha, bixlozone 40 SC (bixlozone) at 750 g/ha with cloquintocet at 1000 mL/ha, metribuzin 70 WP (metribuzin) at 150 g/ha with cloquintocet at 1000 mL/ha, metribuzin 210 g/ha, clodinafop-propargyl 12% + metribuzin 42% WG (clodinafop-propargyl + metribuzin) at 210+60 g/ha with surfactant at 1250 mL/ha, weed free and weedy check. The field experiment was laid out in a randomized complete block design with three replicates. Wheat cv. *Unnat PBW 343* was sown on November 17, 2021 and November 14, 2022, at a seed rate of 100 kg/ha with 20 cm row spacing. Each plot measured 5.0 m × 5.0 m (25 m^2). Herbicides were sprayed using a knapsack sprayer with a flat fan nozzle on December 14, 2021 and December 14, 2022, during the first and second year, respectively, one day before first irrigation to crop at 28 days after seeding (DAS) in 2021-22 and 30 DAS in 2022-23 using volume of water 500 L/ha except metribuzin 150 g/ha with cloquintocet at 1000 mL/ha, metribuzin 210 g/ha, clodinafop-propargyl + metribuzin 210 + 60 g/ha with surfactant at 1250 mL/ha as these were applied as post emergence (35 DAS). In the weed-free plots, weeds were manually removed using khurpa. All standard cultivation practices were followed for raising the crop, except for weed management interventions. Fertilization was done at the rate of 125 kg N and 62 kg P/ha.

Recommended plant protection measures were taken against insect pests and diseases to ensure a healthy crop. Manual harvesting of crop was carried out on April 19 2022, and April 22, 2023, respectively.

The data on weeds was recorded with a quadrat (50 cm × 50 cm) from two different locations in each plot at 15, 30, 45 and 60 days after application (DAA) of pre-mix herbicide combination. Bio-efficacy in terms of weed control was recorded by taking observations of weed density and biomass. Species-wise weed density was recorded at 15, 30, 45 and 60 DAA. The biomass of weed species was observed at 60 DAA. To analyse and interpret weed density and biomass, the average of both quadrats was converted into no./m^2 and g/m^2, respectively. Weed control efficiency was calculated based on weed biomass using the formula suggested by Mani *et al.* (1973), as shown below:

$$\text{Weed control efficiency (\%)} = \frac{\text{WBc} - \text{WBt}}{\text{WBc}} \times 100$$

where, WBc is the weed biomass in untreated control and WBt is the weed biomass in treated plot.

The recorded data were analyzed using CPCS-1 software (version 3.2.3) developed by Cheema and Singh (1991). Differences among treatment means were tested for significance through Fisher's Least Significant Difference (LSD) procedure at a 5% probability level (p=0.05) as outlined by Cochran and Cox (1957). To achieve normality in weed data distribution, square root transformation was performed before statistical analysis.

RESULTS AND DISCUSSION

Effect on weeds

During both the years of field study, the experimental site was predominant with weed flora of grasses like *P. minor* and broad-leaved weeds like *Medicago denticulata* and *Rumex dentatus etc.*

At 15, 30, 45 and 60 DAA, bixlozone + metribuzin 750-900 g/ha with cloquintocet at 1000 mL/ha recorded statistically at par density of *P. minor* and were significantly lower than all other herbicidal treatments (**Table 1-2**). Bixlozone + metribuzin 750 g/ha with cloquintocet at 1000 mL/ha resulted in reduction in the *P. minor* density of 97.1, 97.7, 97.9 and 98.1% in 2021-22 and 100, 96.7, 97.7 and 98.1% in 2022-23 at 15, 30, 45 and 60 DAA, respectively over weedy check. Moreover, bixlozone + metribuzin 600-900 g/ha with cloquintocet at 1000 mL/ha and clodinafop-propargyl + metribuzin 270 g/ha with surfactant at 1250 mL/ha recorded statistically at par density of *M. denticulata* and *R. dentatus* at 15, 30, 45 and 60 DAA and significantly lower than all other herbicide treatments except in 2021-22 at 45 and 60 DAA. During both years of study, at 15 and 30 DAA

Table 1. Effect of herbicide treatments on weed density(no./m^2) at 15 and 30 days after herbicide application in wheat

Treatment	Dose (g/ha)	Grass				Broad-leaved weeds							
		P. minor				*M. denticulata*				*R. dentatus*			
		15 DAA		30 DAA		15 DAA		30 DAA		15 DAA		30 DAA	
		2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
Bixlozone + metribuzin with cloquintocet at 1000 mL/ha	600	1.63 (2)	1.37 (1)	2.02 (3)	1.60 (2)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Bixlozone + metribuzin with cloquintocet at 1000 mL/ha	750	1.24 (1)	1.10 (0)	1.41 (1)	1.20 (1)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Bixlozone + metribuzin with cloquintocet at 1000 mL/ha	900	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.33 (1)	1.00 (0)
Bixlozone with cloquintocet at 1000 mL/ha	750	2.51 (5)	2.51 (5)	2.76 (7)	3.15 (9)	2.85 (7)	2.85 (7)	2.95 (8)	3.21 (9)	2.45 (5)	2.44 (5)	1.00 (0)	2.62 (6)
Metribuzin with cloquintocet at 1000 mL/ha	150	3.16 (9)	1.86 (2)	3.55 (12)	3.04 (8)	2.40 (5)	1.46 (1)	2.44 (5)	2.44 (5)	2.16 (4)	1.38 (1)	2.24 (4)	1.65 (2)
Metribuzin	210	2.02 (3)	3.15 (9)	2.23 (4)	3.86 (14)	1.37 (1)	2.38 (4)	1.53 (1)	3.26 (9)	1.20 (1)	2.12 (3)	1.00 (0)	2.62 (6)
Clodinafop propargyl + metribuzin with surfactant at 1250 mL/ha	270	1.78 (2)	1.49 (1)	2.12 (4)	1.69 (2)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
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)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Weedy check	-	6.01 (35)	3.93 (14)	6.73 (44)	5.44 (30)	2.77 (7)	2.92 (7)	2.89 (7)	3.30 (10)	2.87 (7)	2.88 (7)	3.31 (10)	2.98 (8)
LSD (p=0.05)		0.30	0.19	0.48	0.29	0.35	0.35	0.22	0.47	0.08	0.28	0.37	0.43

*Figures in parentheses are original means. Data were subjected to square root transformation and in 2022-23 at 45 and 60 DAA, bixlozone + metribuzin 600 g/ha recorded complete (100%) control of *M. denticulata* and *R. dentatus* density over weedy check. In 2021-22, at 30 DAA, bixlozone 750 g/ha with cloquintocet at 1000 mL/ha and metribuzin 210 g/ha recorded statistically at par density of *R. dentatus* with bixlozone + metribuzin 600 g/ha with cloquintocet at 1000 mL/ha. Similarly, metribuzin 150 g/ha with cloquintocet at 1000 mL/ha recorded statistically at par density of *P. minor* (at 45 and 60 DAA) and *R. dentatus* (at 45 DAA) with bixlozone + metribuzin 750 g/ha with cloquintocet at 1000 mL/ha. Due to a different mode of action (DOXP inhibitor), bixlozone could be an effective herbicide for the control of herbicide-resistant weeds in wheat fields (Wu *et al.* 2022). As a synthetic organic compound from the triazine group, metribuzin is widely used as a pre- and post-emergence herbicide to control grass and broad-leaved weeds in wheat with the mode of action of photosynthesis inhibition (Rubio *et al.* 2014). The synergistic effect of both the combined molecules might have inhibited the growth of newly germinated weed seeds or seedlings. Therefore, during the initial periods of crop growth, total weed density was significantly less. Bixlozone + metribuzin was found to be phyto-toxic to wheat crop after application and resulted in drooping of leaves and yellowing and bleaching of the crop but wheat recovered within 15-25 days.

Bixlozone + metribuzin 750-900 g/ha with cloquintocet at 1000 mL/ha recorded statistically similar biomass of *P. minor* and were significantly lower than all other herbicide treatments except metribuzin with cloquintocet 150 g/ha during 2021-22. Bixlozone + metribuzin 750 g/ha with cloquintocet at 1000 mL/ha recorded 97.6% in 2021-22 and 98.7% in 2022-23 reduction of *P. minor* biomass at 60 DAA, respectively over the weedy check. Moreover, bixlozone + metribuzin 600-900 g/ha with cloquintocet at 1000 mL/ha and clodinafop-propargyl + metribuzin 270 g/ha with surfactant at 1250 mL/ha recorded statistically at par biomass of *M. denticulata* and *R. dentatus* at 60 DAA and significantly lower than all other herbicide treatments except *R. dentatus* in 2021. Bixlozone + metribuzin at 600 g/ha recorded cent percent (100%) reduction in biomass of *M. denticulata* and *R. dentatus* over weedy check except *R. dentatus* biomass during 2021-22. In 2021-22, metribuzin 150 g/ha with cloquintocet at 1000 mL/ha recorded statistically at par biomass of *P. minor* with bixlozone + metribuzin 750 g/ha with cloquintocet at 1000 mL/ha (**Table 3**). This might be due to the fact that combined formulation of two herbicides known for controlling grass and broad-leaved weeds provided effective control of all the weeds leading to lower weed biomass. These results confirm the findings of Malik *et al.* (2013) and Sudha *et al.* (2016), who reported that application of pre-mix herbicides significantly

Table 2. Effect of different herbicide treatments on weed density (no./m^2) at 45 and 60 days after herbicide application in wheat

Treatment	Dose (g/ha)	Grass				Broad-leaved weeds							
		P. minor				*M. denticulata*				*R. dentatus*			
		45 DAA		60 DAA		45 DAA		60 DAA		45 DAA		60 DAA	
		2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
Bixlozone + metribuzin with cloquintocet at 1000 mL/ha	600	2.06 (3)	1.69 (2)	2.14 (4)	1.94 (3)	1.77 (2)	1.00 (0)	1.81 (2)	1.00 (0)	2.43 (5)	1.00 (0)	2.07 (3)	1.00 (0)
Bixlozone + metribuzin with cloquintocet at 1000 mL/ha	750	1.49 (1)	1.29 (1)	1.51 (1)	1.36 (1)	1.24 (1)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Bixlozone + metribuzin with cloquintocet at 1000 mL/ha	900	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Bixlozone with cloquintocet at 1000 mL/ha	750	2.38 (5)	3.35 (10)	2.44 (5)	3.95 (14)	2.23 (4)	3.73 (13)	3.02 (8)	3.98 (15)	1.58 (2)	3.86 (14)	1.67 (2)	2.98 (8)
Metribuzin with cloquintocet at 1000 mL/ha	150	1.00 (0)	1.67 (2)	1.00 (0)	2.43 (6)	1.72 (2)	1.88 (3)	1.63 (2)	2.92 (9)	1.19 (1)	1.90 (3)	1.38 (1)	2.07 (4)
Metribuzin	210	2.20 (4)	2.44 (5)	2.51 (5)	3.86 (14)	1.90 (3)	2.64 (6)	1.72 (2)	4.03 (16)	2.19 (4)	2.85 (7)	1.73 (2)	3.64 (12)
Clodinafop propargyl + metribuzin with surfactant at 1250 mL/ha	270	2.17 (4)	1.85 (2)	2.21 (4)	2.04 (3)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
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)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Weedy check	-	7.00 (48)	6.63 (44)	7.39 (54)	7.29 (52)	3.15 (9)	3.39 (11)	4.26 (17)	4.24 (17)	3.31 (10)	3.10 (9)	3.91 (14)	3.60 (12)
LSD(p=0.05)		0.53	0.35	0.56	0.47	0.38	0.27	0.22	0.81	0.51	0.29	0.29	0.53

*Figures in parentheses are original means. Data were subjected to square root transformation reduced the biomass of grass and broad-leaved weeds in wheat. As weed seedlings emerge, their meristematic tissues come into contact with the herbicide, absorb it, and subsequently exhibit phytotoxic symptoms, leading to suppressed growth and reduced biomass (Onwuchekwa-Henry *et al.* 2023).

At 60 DAA, the highest control efficiency of *P. minor* (93.5-100% in 2021 and 94.9-100% in 2022-23), *M. denticulata* (100% in both years) and *R. dentatus* (62.2-100% in 2021-22 and 100% in 2022-23) was recorded with bixlozone + metribuzin 600-900 g/ha with cloquintocet at 1000 mL/ha which were similar to the weed control efficiency achieved with clodinafop-propargyl + metribuzin 270 g/ha with surfactant at 1250 mL/ha for *P. minor* (92.7% in 2021-22 and 94.3% in 2022-23), *M. denticulata* (100% in both years) and *R. dentatus* (100% in 2022-23 only) (**Figure 1**). The suppression of weed growth, resulting from the application of various herbicides, likely contributed to reduced weed proliferation and increased mortality, as outlined earlier. These factors collectively appear to be the primary reasons for the lower weed biomass accumulation, which in turn led to higher weed control efficiency (Yadav *et al.* 2021). The herbicide mixture strategy would not only offer broad-spectrum weed control but also help delay the development of herbicide resistance in weeds, manage existing herbicide resistance issues (Lakra *et al.* 2022).

Effect on wheat

Wheat grain yield in various treatments ranged from 4.30 t/ha to 6.06 t/ha in 2021-22 and 4.15 t/ha to 5.54 t/ha in 2022-23. Bixlozone + metribuzin 600-750 g/ha with cloquintocet at 1000 mL/ha and clodinafop-propargyl + metribuzin 270 g/ha with surfactant at 1250 mL/ha recorded at par grain yield of wheat and was significantly higher than all other herbicide treatments. The bixlozone + metribuzin 600 g/ha with cloquintocet at 1000 mL/ha resulted in 24.4% and 29.4% higher wheat grain yield than weedy check (**Table 3**). The reduction in weed biomass under herbicide treatments may be ascribed to the better development of plant reproductive structures and greater translocation of photosynthates towards the sink, resulting from effective weed suppression and minimized competition for vital resources such as moisture, nutrients, space, and light, which ultimately enhanced crop productivity (Kumar *et al.* 2017).

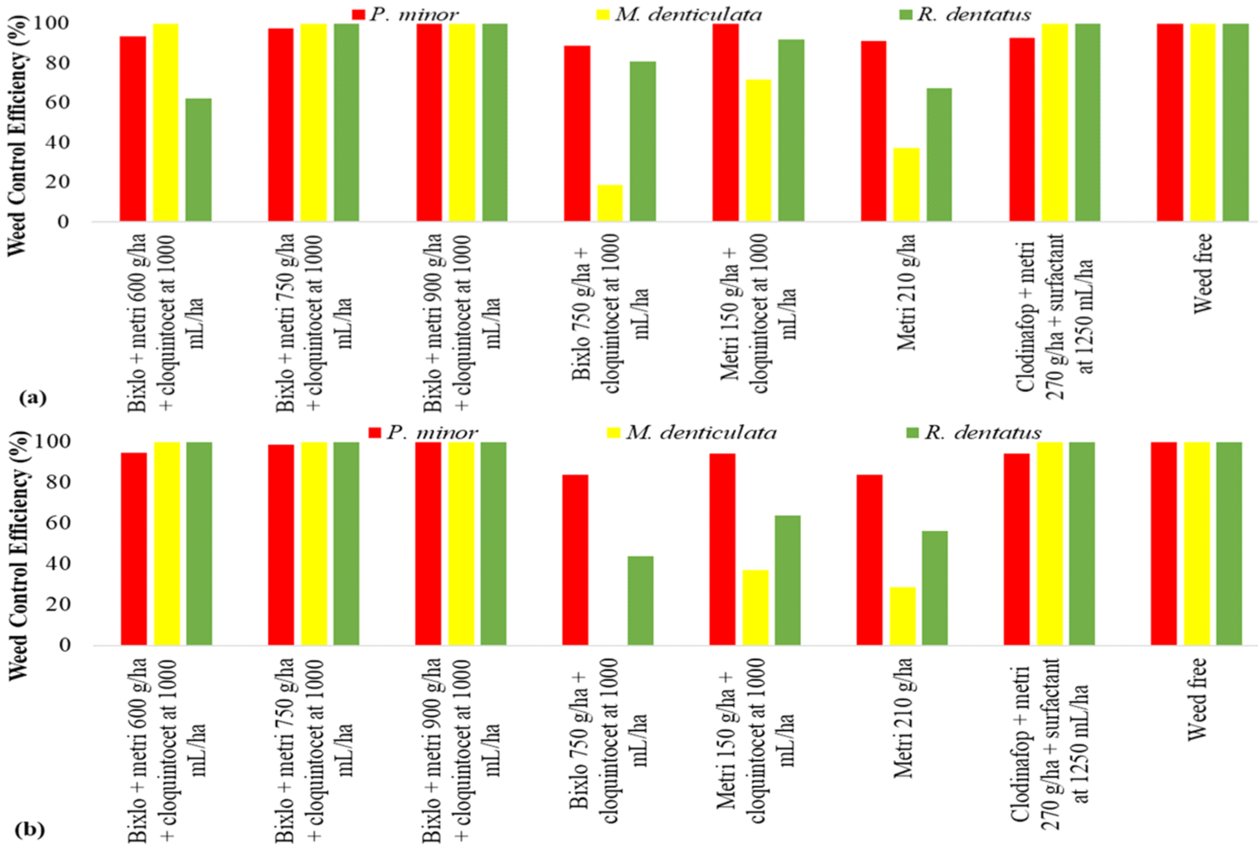

Figure 1. Weed control efficiency (%) of herbicide treatments in wheat at 60 DAA (a) 2021-22 (b) 2022-23

Table 3. Effect of different herbicide treatments on weed biomass (g/m^2) at 60 DAA and grain yield in wheat during *Rabi* 2021-22 and 2022-23

Treatment	Dose (g/ha)	Grass *P. minor* 2021-22	Grass *P. minor* 2022-23	Broad-leaved weeds *M. denticulata* 2021-22	Broad-leaved weeds *M. denticulata* 2022-23	Broad-leaved weeds *R. dentatus* 2021-22	Broad-leaved weeds *R. dentatus* 2022-23	Wheat grain yield (t/ha) 2021-22	Wheat grain yield (t/ha) 2022-23
Bixlozone + metribuzin with cloquintocet at 1000 mL/ha	600	2.99(8)	2.89(7)	1.00(0)	1.00(0)	3.85(14)	1.00(0)	5.35	5.37
Bixlozone + metribuzin with cloquintocet at 1000 mL/ha	750	1.90(3)	1.75(2)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	5.25	5.26
Bixlozone + metribuzin with cloquintocet at 1000 mL/ha	900	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	4.96	4.72
Bixlozone with cloquintocet at 1000 mL/ha	750	3.84(14)	5.00(25)	5.16(26)	5.91(35)	2.72(7)	6.10(36)	4.53	4.93
Metribuzin with cloquintocet at 1000 mL/ha	150	1.00(0)	3.11(9)	3.11(9)	4.82(22)	1.67(3)	4.89(23)	4.86	5.07
Metribuzin	210	3.46(11)	5.1(25)	4.49(20)	5.15(25)	3.64(12)	5.36(28)	4.71	4.82
Clodinafop propargyl + metribuzin with surfactant at 1250 mL/ha	270	3.11(9)	3.07(9)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	5.30	5.26
Weed free	-	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	6.06	5.54
Weedy check	-	11.15(124)	12.56(157)	5.70(32)	5.99(35)	6.19(37)	8.07(64)	4.30	4.15
LSD(p=0.05)		0.99	0.94	0.66	0.47	0.63	0.48	0.23	0.16

*Figures in parentheses are original means. Data were subjected to square root transformation, DAA = Days after application

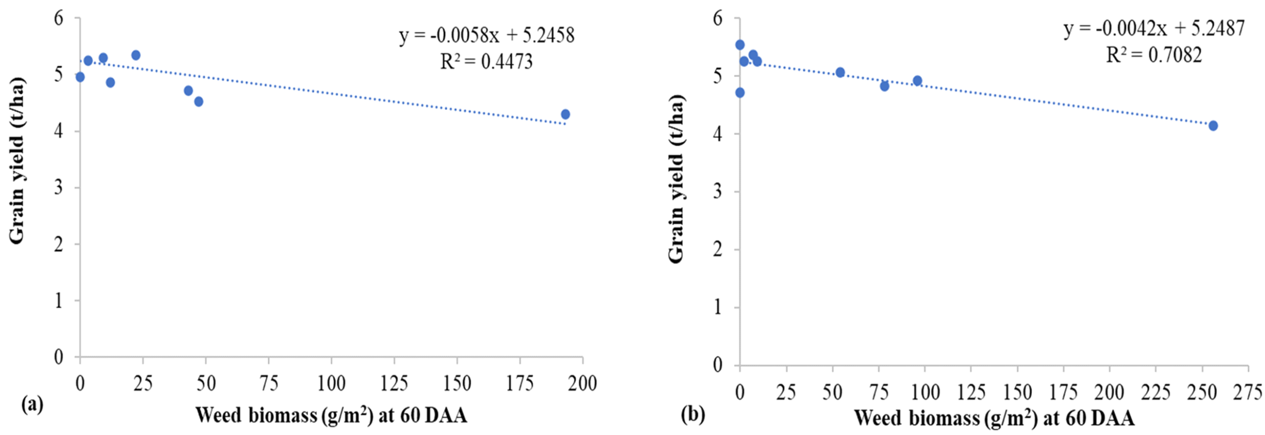

Figure 2. The relationship of the wheat grain yield (t/ha) with weed biomass (g/m^2) at 60 DAA (a) 2021-22 (b) 2022-23

The linear regression analysis illustrates the relationship between total weed biomass at 60 DAA and grain yield of wheat (**Figure 2**). A strong negative linear correlation was observed, with R^2 values of 0.4473 and 0.7082 at 60 DAA for 2021-22 and 2022-23, respectively. This indicates that weed biomass accounted for 45% of the yield variation in 2021-22 and 71% in 2022-23. As total weed biomass increased, there was a corresponding decrease in wheat grain yield. The findings highlight a significant influence of weed control treatments on both weed biomass at 60 DAA and grain yield.

Based on a two-year study, it is concluded that early post-emergence application at 28-30 DAS (one day before first irrigation) of bixlozone + metribuzin 600-750 g/ha with safener cloquintocet at 1000 mL/ha provided effective control of herbicide resistant *P. minor* and associated broad-leaved weeds in wheat.

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