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Integrating Malathion with Wheat Herbicides for Managing Resistance in *Phalaris minor*

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ABSTRACT: For sustainable wheat production management of *Phalaris minor* are the major challenge. A field experiment with three replications was conducted at Research Farm of Agronomy, CCS Haryana Agricultural University, Hisar using seven post-emergence herbicides, including clodinafop 12% + metribuzin 42% (RM) (Shagun), clodinafop 9% + metribuzin 20% (RM) (ACM-9), metribuzin, pinoxaden, sulfosulfuron, isoproturon, meso+iodosulfuron, and their integration with malathion at various doses along with weed free and weedy check treatments. After the crop had been sown for 34 days, all of the treatments were applied. When using herbicides alone, pinoxaden consistently outperformed all other herbicides in terms of taller plants and higher yield attributes. However, when using herbicides in combination with malathion, all but malathion *fb* pinoxaden, the values of these parameters significantly decreased. Wheat plots with no weeds produced a greater grain yield (5764 kg ha^{-1}), which was closely followed by the plots treated with 50g/ha of pinoxaden. The phytotoxicity of various herbicidal treatments decreased over successive intervals, and none of the treatments still had any detectable phytotoxicity at 60 DAT. When herbicides were used in conjunction with malathion as compared to alone, a higher level of weed control efficiency was observed. Pinoxaden applied at 50 g ha^{-1} was determined to be the most effective treatments for managing weeds and had the greatest B:C of 1.82 followed by malathion *fb* pinoxaden (1000 *fb* 50 g ha^{-1}) and clodinafop 9% + metribuzin 20% (RM) (ACM-9) at 174 g ha^{-1}.

Keywords: *Phalaris minor*, weed, herbicide resistance, wheat, metribuzin, clodinafop, pinoxaden, malathion.

INTRODUCTION

A member of the *Poaceae* family, wheat (*Triticum aestivum* L.) is a staple food and the most widely cultivated cereal crop in the world and its reliable production and delivery are essential for food security. Globally, it is grown on an area of 219.0 million hectares, producing 760.9 million tonnes with a productivity of about 3474 kg ha^{-1} (FAOSTAT, 2021). India supplies 14.3% of the world's total wheat cultivable area, producing 107.6 million tonnes with an average yield of 3431 kg ha^{-1}. The predominant wheat-growing region in India is the North-West Indo Gangetic Plains (N-W IGPs), which includes three Indian states of Punjab, Haryana, and Uttar Pradesh. This region produces 63.3 million tonnes of wheat from an area of 15.9 million hectares, yielding a productivity of 3979 kg ha^{-1} (Anonymous, 2022). In the majority of the northern states, including Punjab, Haryana, and U.P., wheat productivity has plateaued. Nevertheless, there is a lot of room to improve agronomic practices (particularly weed management) in order to raise productivity because there is a discrepancy between the yield potential of high producing cultivars and the yield that farmers actually achieve in their fields. Numerous biotic and abiotic variables contribute to the decreased wheat yield. One of the main biotic variables that severely lower wheat production is weeds. Wheat productivity can be increased even further with efficient weed control and fine-tuned agronomic procedures. The weeds are one of the main reasons preventing wheat and other crops from yielding to their full potential, and the losses they cause are dependent on their type, their density and the surrounding environment. Depending on environmental factors like humidity, temperature, and moisture availability, type of soil, cultural practices, and crop rotation practices used, wheat crop is typically infested with both grassy and broadleaf weeds. One of the main causes of poorer yield, productivity declines of 15–40% or more, and lower product quality is weeds (Singh *et al.*, 2019). In north-west India, *P. minor* is the most common grassy weed of wheat (Singh *et al.*, 1995). Hooda *et al*. (2017) reported that uncontrolled weeds, mainly *P. minor* and *Avena ludoviciana*, reduced wheat yield by 24 percent. According to Malik and Singh (1991), the percentage of *P. minor* incidence was 94% in rice-wheat cropping systems and 48% in non-rice-wheat cropping systems. The main weed infesting wheat fields in India is *P. minor*. It has a C_3 photosynthetic pathway and self-pollinates (2n = 28), just like wheat plants do. It belongs to grassy family *Poaceae* and it is a monocot weed plant. In various regions of India, it is also known by the local names Kanki, Mandusi Sitti and Gullidanda. Due to wheat's similar form and evolving requirements, it turned out to be more nefarious. Numerous herbicides have been suggested for use in wheat crop as a dependable, cost-effective strategy to address the *P. minor* issue. Uncontrolled application of herbicides in wheat had; however, resulted in resistance problem (Malik and Singh 1993). Resistance in *P. minor* has been developed as a result of isoproturon use in rice-wheat cropping systems over a period of 10 to 15 years (Malik and Singh 1995; Singh *et al.*, 1997). Due to isoproturon's failure to control *P. minor* from infesting wheat, its recommendation was withdrawn in 1998, whereas, failure of fenoxaprop to control *P. minor* resulted its use down within a few years which has decreased to nearly nil. The situation is becoming more complicated every year, as seen by the irregular reports of resistance to clodinafop and even sulfosulfuron against a few biotypes of *P. minor* in Haryana (Yadav and Malik 2005; Singh, 2007). *Phalaris minor* and *Avena ludoviciana* were effectively controlled (76 to 100%) by clodinafop in Haryana at doses of 60, 90, and 120 g ha^{-1}; however, a lower dose of 30 g ha^{-1} proved ineffective (Hooda *et al.*, 2014; 2017). There is currently no one herbicide that can successfully manage resistant *P. minor*. Since the addition of the cytochrome P450 inhibitors, 1-aminobenzotraizole (ABT) and piperonylbutoxide (PBO) to isoproturon caused a loss of resistance and inhibited its degradation in resistant biotypes, studies on the mechanism of development of isoproturon resistance in *P. minor* have shown that there is an increased degradation of isoproturon by increased activity of the enzyme cytochrome P450 monooxygenase (Singh *et al.*, 1998). Malathion, an acetylcholinesterase inhibitory organophosphate insecticide, has been utilised to identify the participation of this enzyme in the herbicides' degradative process (Christopher *et al*., 1994). By inhibiting Cytochrome P450 monoxygenase enzymes, it may be able to overcome *P. minor's* isoproturon resistance (Dhawan and Gupta, 2007). The single mode of action of a herbicide should not be relied upon exclusively as this has led to an increase in weed difficulties and the quick evolution of multiple herbicide resistance, both of which pose a threat to wheat production (Malik and Singh 1995). To widen the range of weed control, it is necessary to evaluate some herbicides with newer modes of action (MOA), either individually or in a tank mix. We must rely on the present herbicides, either sequentially or in their mixes, as the synthesis of herbicides of newer MOA is gradually very slow. Combinations of herbicides can slow the spread of resistant populations. Combinations of herbicides are required to manage complex weed flora (grass and broadleaf weeds) and to offer long-term residual weed control. Tank mix combinations or ready mixtures are preferable to sequential application because they can be applied more quickly and inexpensively. In addition to controlling complex weed flora, herbicide mixtures will aid in regulating and postponing the problem of herbicide resistance (Wrubel and Gressel 1994).

For controlling herbicidal resistance in *P. minor* as well as for the sustainability of wheat crop production, unconventional strategies are crucial. The application of herbicide combinations with two sites or more than two sites of chemistries is a significant approach to eradicate resistant weeds and stop the emergence of herbicide resistance. This study aimed to determine the efficiency of several herbicides and their combinations with malathion at a range of doses to manage population of noxious weed *P. minor* in wheat crop. Additionally, the impacts of various chemical mixtures on the development and output of wheat crop plants were investigated.

MATERIALS AND METHODS

During *Rabi* season of 2019-20, a field study was done at Research Area of department of Agronomy, CCS Haryana Agricultural University, Hisar. The experimental location is situated in the north-western region of India at 29°16'N latitude and 75°7'E longitude, with a mean sea height of 215.2 m. The region experiences a semiarid climate with very hot summers and mild winters. Hisar's climate is primarily characterised by dryness, temperature extremes, and little rainfall. Summertime maximum daytime temperature range from 104 and 115 °F (40 and 46 °C), while, it fluctuates between 1.5 and 4 °C in the winter. In Hisar, 5 to 100% relative humidity is typical. The city of Hisar is situated on the southernmost edge of the southwest monsoon belt where majority of the 429 mm (16.9 in) of yearly rainfall falls during July and August. In the experimental field, the topsoil was a sandy loam with low levels of organic carbon and nitrogen, medium levels of readily available phosphorus, high levels of potassium, and a slightly alkaline pH (7.73). Wheat variety WH 1105 was sown on November 19, 2019, using a seed-cum-fertilizer drill with a 20-cm line-to-line spacing and 100 kg of seed per hectare. The crop was harvested on April 16, 2020.

In the experimental trial, there were seven post-emergence herbicides, including clodinafop 12% + metribuzin 42% (RM) (Shagun), clodinafop 9% + metribuzin 20% (RM) (ACM-9), metribuzin, pinoxaden, sulfosulfuron, isoproturon, meso+iodosulfuron, and their integration with malathion at various doses along with weed free and weedy check treatments (Table 1). After 34 days of sowing of wheat crop, malathion was sprayed 1-2 hours before to the application of the herbicides. A knapsack sprayer fitted with flat fan nozzles was utilized to spray these chemicals with a water volume of 375 L ha^{-1}. Herbicides were applied in specific dosages either singly or in a tank mix. Three replications were used in the randomised block design of the experiment. Plant phyto-toxicity is a visual observation which was observed at 7, 15, 30, 45 and on 60 days after treatment (DAT) via 0-10 scale (0 represents the absence of mortality symptoms and 10 shows all possible mortality symptoms in plants). Quadrates (0.25 m^2) were randomly positioned in each plot at various intervals to measure weed density and the real values were square-root transformed ($\sqrt{x+1}$) for study. *Phalaris minor*, with a share of over 90%, was the most prevalent weed flora in the experimental field. Broadleaf weeds (*Coronopus didymus, Chenopodium album, Medicago denticulate, Anagallis arvensis, Lathyrus aphaca, Melilotus indicus, Cirsium arvense* etc.) made up the majority of the minor weed species that were physically removed. Weeds collected using a quadrate were dried in an oven at 65 ± 5° to determine the dry matter accumulation (g/m^2) of the weeds. The weed control efficiency (WCE) was estimated using a formula as under:

$$\text{WCE (\%)} = \frac{W_2 - W_1}{W_2} \times 100$$

Here,
W_2 = Weeds' dry weight in the weedy check plot
W_1 = Weeds' dry weight in treatment plot

Three tagged wheat plants from each plot were used for their plant height measured from the soil's surface to the ear head after heading. For the statistical study, the average plant height (cm) was used. From each plot, five randomly chosen spikes from five randomly chosen plants were taken, and the length of each spike was measured in centimeters (cm). Spike length (cm) was measured from the base of the peduncle (lower spikelet) to the top of the spikelet. The grains and spikelets from the spikes chosen for assessing spike length were separated, and the overall numbers of grains were measured, averaged, and expressed as grains per spike. The bundles were sun dried for 4-5 days after harvesting the net area of each individual plot, weighed before threshing, and then recorded separately as biological yield after being converted into kg ha^{-1} and then it was threshed and weighed for grain yield (kg ha^{-1}). To calculate the straw yield, the grain yield that was so calculated was subtracted from the harvested crop's biomass (biological yield). By using the following expression, the harvest index, a ratio between grain yield and biological yield, was calculated.

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

Based on current market values for inputs and outputs, the cost of cultivation and gross income (Rs ha^{-1}) of various treatments were estimated, and then B:C was determined. The statistical methods of analysis of variance (ANOVA) as outlined by Panse and Sukhatme (1985) were used to analyse the experimental data.

RESULTS AND DISCUSSION

Effect of different wheat herbicides alone or integrated with malathion on WCE (%) of *Phalaris minor* and plant phytotoxicity.

At 120 DAS, the WCE was much higher in plots treated with various herbicides either alone or in combination with malathion (Table 1). When compared to weedy check plots, all plots where herbicides were sprayed alone or in combination with malathion showed a significant improvement in WCE. WCE at harvest ranged from 34 to 94 percent among the treatments when herbicides were not integrated with malathion. All herbicides resulted into more than eighty percent weed control efficiency except isoproturon and metribuzin. The maximum WCE (93.78%) at harvest was obtained when metribuzin and clodinafop (clodinafop 12% + metribuzin 42%) were combined. Rani *et al.* (2021) reported similar findings of improved weed control and greater WCE with metribuzin-based combinations. The WCE with isoproturon treatment remained much lower than that of the other herbicides. An improvement in WCE was seen in the treatments where malathion was integrated with the application of herbicides. In comparison to alone application of herbicides, the WCE of several herbicides was significantly improved after being applied simultaneously with malathion. Combination of malathion with ACM-9, Shagun, pinoxaden, and meso+iodosulfuron produced a weed-free environment, and some herbicides had WCE of up to 100%. Malathion, an inhibitor of cytochrome P-450 enzyme, has been used to determine the role of this enzyme in the degradation process of the herbicides because it decreased maize's tolerance to the sulfonylurea herbicide primisulfuron by inhibiting this enzyme's dependence on herbicide metabolism (Kreuz and Pfister 1992; Christopher *et al*., 1994).

Herbicidal phytotoxicity decreased with passage of time i.e. at 15, 30, 45 DAT reaching zero at 60 DAT (Table 1). The highest phytotoxicity score (6.3) was recorded at 7 DAT for malathion *fb* meso + iodosulfuron (1000 *fb* 14.4 g ha^{-1}), followed by malathion *fb* sulfosulfuron (1000 *fb* 25 g ha^{-1}) (5.3) and malathion *fb* Shagun (1000 *fb* 270 g ha^{-1}) (4.3). These scores decreased throughout time, i.e. at 15, 30, and 45 DAT, and no treatment-related phytotoxicity was seen at 60 DAT. Herbicidal phytotoxicity on wheat crop was temporary and no phytotoxicity at 45 DAT was observed on wheat crop due to various treatments except in malathion *fb* meso + iodosulfuron (1000 *fb* 14.4 g ha^{-1}) and malathion *fb* sulfosulfuron (1000 *fb* 25 g ha^{-1}) which caused little phytotoxicity (0.5) upto 45 DAT. At any crop stage, neither pinoxaden (50 g ha^{-1}) nor isoproturon (1000 g ha^{-1}) used alone or in combination with malathion resulted in any detectable plant phytotoxicity. Except for pinoxaden (50 g ha^{-1}) and isoproturon (1000 g ha^{-1}) applied alone or combined with malathion at any stage of the crop cycle, the plant phytotoxicity was significantly higher following the application of herbicides integrated with malathion than it was following the application of herbicides alone. There is a synergistic interaction between some organophosphate insecticides and herbicides that increases phytotoxicity in crop plants like rice, maize, and wheat as well as grass weeds like *Echinochloa phyllopogon* or *Lolium rigidum*. These insecticides have been shown to have inhibitory effects on specific P-450 enzymes involved in herbicide detoxification pathways (Tardif and Powles 1999; Yasuor *et al*., 2009). Highly reactive and chemically varied compounds, organophosphate insecticides have an atom of phosphorous attached to either sulphur or oxygen in a covalent bond. The competition between herbicides and insecticides in P-450-mediated processes as well as the oxidative desulphurization of the organophosphate insecticide can be used to explain the increased herbicide toxicity (Christopher *et al.*, 1994). However, there are instances where the opposite effect is observed and the herbicide's phytotoxicity and plant damage are reduced by the organophosphate insecticide. Applying the organophosphate insecticides phorate and disulfoton, for instance, can protect cotton plants by preventing the oxidation of the herbicide clomazone by the P-450 enzyme and the consequent generation of phytotoxic clomazone metabolites (Ferhatoglu *et al*., 2005).

Table 1: Effect of herbicides integrated with malathion on WCE (%) and plant phytotoxicity (0-10 scale) in wheat.

Treatments	Dose (ml or g/ha)	WCE (%)	Plant phytotoxicity (0-10 scale)				
			Days after treatment				
		120 DAS	7	15	30	45	60
T_1 : ACM-9 (clodinafop 9% + metribuzin 20%)	174	87.46	2.6	1.6	1.0	0.0	0.0
T_2 : Shagun (clodinafop 12%+metribuzin 42%)	270	93.81	3.6	2.3	1.3	0.0	0.0
T_3 : Metribuzin	175	76.55	3.0	2.3	1.0	0.0	0.0
T_4 : Isoproturon	1000	34.36	0.0	0.0	0.0	0.0	0.0
T_5 : Sulfosulfuron	25	82.74	2.3	1.6	0.5	0.0	0.0
T_6 : Meso+iodosulfuron	14.4	92.18	3.6	2.3	1.0	0.0	0.0
T_7 : Pinoxaden	50	89.09	0.0	0.0	0.0	0.0	0.0
T_8 : Malathion *fb* ACM-9	1000 *fb* 174	98.37	3.3	2.3	1.0	0.0	0.0
T_9 : Malathion *fb* Shagun	1000 *fb* 270	100.00	4.3	3.0	1.6	0.0	0.0
T_{10} : Malathion *fb* metribuzin	1000 *fb* 175	85.67	4.0	2.6	1.3	0.0	0.0
T_{11} : Malathion *fb* isoproturon	1000 *fb* 1000	44.14	0.0	0.0	0.0	0.0	0.0
T_{12} : Malathion *fb* sulfosulfuron	1000 *fb* 25	96.74	5.3	3.6	1.6	0.5	0.0
T_{13} : Malathion *fb* meso+iodosulfuron	1000 *fb* 14.4	100.00	6.3	4.3	2.0	0.5	0.0
T_{14} : Malathion *fb* pinoxaden	1000 *fb* 50	98.37	0.0	0.0	0.0	0.0	0.0
T_{15} : Weed free	-	100.00	0.0	0.0	0.0	0.0	0.0
T_{16} : Weedy check	-	0.00	0.0	0.0	0.0	0.0	0.0

Effect of wheat herbicides used alone or in combination with malathion on plant growth, yield attributes and yields of wheat. The statistical data clearly show that weed-free cultivation increased crop yield features such as effective tillers (408 tillers/m^2) and biological yield (14267 kg ha^{-1}) as well as grain yield (5764 kg ha^{-1}) which remained significantly higher than the effects of all other treatments (Table 2). The crop yield (grain yield, straw yield, and biological yield) was significantly higher under pinoxaden among the treatments where herbicides were applied without integrating malathion, and it remained significantly higher than all other herbicides except ACM-9. However, increased biological and grain production may be linked to better plant growth and higher yield attributes due to decreased weed competition after herbicide application. Wheat grain yield is significantly influenced by biomass production; as a result, the more biomass a crop produces, the more photosynthates it can translocate to the grain during grain filling period. Under malathion *fb* pinoxaden, which remained significantly higher than all other treatments except ACM-9, significantly more wheat yield attributes and crop yield were recorded among the treatments where herbicides were sprayed with integration of malathion. This might be because herbicide treatments were effective at reducing weeds, which led to less competition for various resources and more food moving from source to sink. Application of the herbicides along with their integration with malathion decreased the wheat crop's yield characteristics and grain yield compared to their alone application with the exception of isoproturon. The values of yield-attributing characteristics of the wheat crop and wheat yield decreased in weedy check treatments, resulting in the lowest values under that condition. Weeds fight for the applied inputs but in wheat principally *P. minor* and broad leaf weeds are the key issue that regularly utilizes the available input and space and causes considerable failure in the economic output. After being sprayed at 34 DAS, the aforementioned chemical combinations significantly reduced the weed growth, resulting in enhancement in yield attributes and crop yield. Furthermore, the wheat plant's quick growth effectively made use of the available resources in the absence of weeds. These results are supported by Chhokar *et al.* (2012).

Effect of wheat herbicides used alone or in combination with malathion on economics of wheat. For evaluation and to determine the best herbicide treatment, the economics of several herbicidal treatments had been computed. The higher net returns were observed in the treatment pinoxaden at 50 g ha^{-1} (Rs. 55490 ha^{-1}) followed by malathion *fb* pinoxaden at 1000 *fb* 50 g ha^{-1} (Rs 52426 ha^{-1}) and

ACM-9 (clodinafop 9% + metribuzin 20%) at 174 g ha^{-1} (Rs. 51489 ha^{-1}) (Table 3). Weed free treatment resulted into maximum cost of cultivation i.e. Rs. 80000 ha^{-1} alongwith net returns of Rs. 48419 and gross returns of Rs. 128419 ha^{-1} and with a benefit cost ratio 1.61. The highest B:C of 1.82 was computed in pinoxaden herbicide treatment sprayed at 50 g ha^{-1}. Weedy check treatment had the lowest gross and net returns with a B:C of 1.56. In general, treatment pinoxaden applied at 50 g ha^{-1} was found most economical to manage weeds followed by malathion *fb* pinoxaden at 1000 *fb* 50 g ha^{-1} and ACM-9 (clodinafop 9% + metribuzin 20%) at 174 g ha^{-1}. Jaidev *et al.* (2012) also reported variation in B:C ratio.

Table 2: Effect of herbicides integrated with malathion on plant height, yield attributes and yield of wheat.

Treatments	**Dose (ml or g/ha)**	**Plant height (cm)**	**Spike length**	**Grains/ spike**	**Grain yield**	**Straw yield**	**Biological yield**
		At harvest	**(cm)**	**(No.)**	**(kg/ha)**	**(kg/ha)**	**(kg/ha)**
T$_1$: ACM-9 (clodinafop 9% + metribuzin 20%)	174	93.5	10.76	67.26	5303	8400	13703
T$_2$: Shagun (clodinafop 12%+metribuzin 42%)	270	92.5	10.30	64.04	5072	8346	13418
T$_3$: Metribuzin	175	91.4	10.53	65.30	5188	8610	13798
T$_4$: Isoproturon	1000	92.5	9.13	60.21	4496	7788	12284
T$_5$: Sulfosulfuron	25	90.4	10.41	64.04	5130	8406	13536
T$_6$: Meso+iodosulfuron	14.4	88.4	10.18	63.79	5015	8287	13302
T$_7$: Pinoxaden	50	96.5	11.12	67.91	5476	8422	13898
T$_8$: Malathion *fb* ACM-9	1000 *fb* 174	89.4	9.95	62.63	4899	8130	13029
T$_9$: Malathion *fb* Shagun	1000 *fb* 270	87.4	9.48	59.29	4669	8019	12688
T$_{10}$: Malathion *fb* metribuzin	1000 *fb* 175	87.4	9.71	60.45	4784	8287	13071
T$_{11}$: Malathion *fb* isoproturon	1000 *fb* 1000	91.4	9.36	57.62	4611	8341	12952
T$_{12}$: Malathion *fb* sulfosulfuron	1000 *fb* 25	86.4	9.71	58.52	4784	8181	12965
T$_{13}$: Malathion *fb* meso+iodosulfuron	1000 *fb* 14.4	83.3	9.48	57.88	4669	8053	12722
T$_{14}$: Malathion *fb* pinoxaden	1000 *fb* 50	95.5	11.00	69.18	5418	8728	14146
T$_{15}$: Weed free	-	101.6	11.70	70.21	5764	8503	14267
T$_{16}$: Weedy check	-	87.4	8.78	53.44	4223	7993	12216
SEm±		0.94	0.16	1.03	79.5	109.1	185.5
C.D.at 5%		3.01	0.45	3.08	219.6	326.4	547.2

Table 3: Economics of applying various herbicides integrated with malathion in wheat crop.

Treatments	**Dose (ml or g/ha)**	**Cost of cultivation (Rs./ha)**	**Gross returns (Rs./ha)**	**Net returns (Rs./ha)**	**B:C**
T$_1$: ACM-9 (clodinafop 9%+metribuzin 20%)	174 g/ha	67810	119299	51489	1.76
T$_2$: Shagun (clodinafop 12%+metribuzin 42%)	270 g/ha	67810	115422	47612	1.70
T$_3$: Metribuzin	175 g/ha	66385	117517	51132	1.77
T$_4$: Isoproturon	1000 g/ha	66235	103870	37635	1.59
T$_5$: Sulfosulfuron	25 g/ha	66610	116741	50131	1.75
T$_6$: Meso+iodosulfuron	14.4 g/ha	67435	114229	46794	1.69
T$_7$: Pinoxaden	50 g/ha	67435	122925	55490	1.82
T$_8$: Malathion *fb* ACM-9	1000 *fb* 174 g/ha	69060	112084	43024	1.62
T$_9$: Malathion *fb* Shagun	1000 *fb* 270 g/ha	69060	108278	39218	1.58
T$_{10}$: Malathion *fb* metribuzin	1000 *fb* 175 g/ha	67635	110410	42775	1.63
T$_{11}$: Malathion *fb* isoproturon	1000 *fb* 1000 g/ha	67485	107724	40239	1.60
T$_{12}$: Malathion *fb* sulfosulfuron	1000 *fb* 25 g/ha	67860	111316	43456	1.64
T$_{13}$: Malathion *fb* meso+iodosulfuron	1000 *fb* 14.4 g/ha	68685	108946	40261	1.59
T$_{14}$: Malathion *fb* pinoxaden	1000 *fb* 50 g/ha	68685	121111	52426	1.76
T$_{15}$: Weed free	-	80000	128419	48419	1.61
T$_{16}$: Weedy check	-	65560	103030	37470	1.56

CONCLUSIONS

According to the current study, use of wheat herbicides both separately and in combination with malathion effectively controlled *P. minor* by achieving higher WCE (%) and increased the growth and yield of wheat. Compared to their solitary application, spraying herbicides integrated with malathion was observed to be more successful at controlling weeds but due to phytotoxicity, yield penalties were there except in pinoxaden and isoproturon. Therefore, pinoxaden (50 g ha^{-1}) can be used for controlling weeds in wheat crops while increasing wheat production and generating economic returns with better weed control efficiency without having any phytotoxic effect on wheat crop.

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Conflict of Interest. None.

REFERENCES

Anonymous (2022). Second advance estimates of production of food grains for 2021-22. Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare.

Chhokar, R. S., Sharma, R. K. and Sharma, I. (2012). Weed management strategies in wheat- A review. *Journal of Wheat Research*, *4*(2), 1-27.

Christopher, J. T., Preston, C. and Powles, S. B. (1994). Malathion antagonizes metabolism-based chlorsulfuron resistance in *Lolium rigidum*. *Pesticide Biochemistry and Physiology*, *49*(3), 172-182.

Dhawan, R. S. and Gupta, S. (2007). Variable response of malathion on isoproturon resistant biotypes of *Phalaris minor* from Haryana and Punjab. *Annals of Plant Protection Sciences*, *15*(2), 469-539.

FAOSTAT (2021). https://www.fao.org/faostat/en/#data/QCL

Ferhatoglu Y., Avdiushko S. and Barrett M. (2005). The basis for the safening of clomazone by phorate insecticide in cotton and inhibitors of cytochrome P450s. *Pesticide Biochemistry and Physiology*, *81*, 59–70

Hooda, V. S., Sangwan, M. and Sewhag. M. (2017). Evaluation of clodinafop-propargyl 15 WDG as a new formulation against weeds in wheat. *Chemical Science Review and Letters*, *6*(21), 315-318.

Hooda, V. S., Singh, S. Kumar, R. Devraj and Sewhag. M. (2014). Evaluation of clodinafop-propargyl 15%WP (Willowood), a new brand of clodinafop, against weeds in wheat. *Haryana Journal of Agronomy*, *30*(2), 109-113.

Jaidev, Singh, S. K., Kumar, R. and Singh, A. K. (2012). Weed management studies in wheat. *International Agronomy Congress*, *2*, 126-127.

Kreuz, K. and Pfister, R. F. (1992). Herbicide-Insecticide Interaction in Maize: Malathion Inhibits Cytochrome P450-Dependent Primisulfuron Metabolism. *Pesticide Biochemistry and Physiology*, *43*(3), 232-240.

Malik, R. K. and Singh, S. (1991). Shift in weed flora of wheat. *Haryana Farming*, *20*, 11-13.

Malik, R. K. and Singh, S. (1993). Evolving strategies for herbicide use in wheat, resistance and integrated weed management. *Proceedings of International Symposium on "Integrated Weed Management for Sustainable Agriculture"*, 18-20 November 1993, Hisar, India, pp. 225-238.

Malik, R.K. and Singh, S. (1995). Little seed canary grass (*Phalaris minor*) resistance to isoproturon in India. *Weed Technology*, 9(3), 419-425.

Panse, V. G. and Sukhatme, P. V. (1985). Statistical method for agricultural workers. ICAR Publication, New Delhi, 87-89.

Rani, S., Kumar, S., Hooda, V. S. and Kumar, S. (2021). Bio-efficacy of metribuzin based herbicide mixtures on weeds and productivity of wheat. *Indian Journal of Agronomy*, *66*(4), 407-412.

Singh, M. K., Mishra, A., Khanal, N. and Prasad, S. K. (2019). Effects of sowing dates and mulching on growth and yield of wheat and weeds (*Phalaris minor Retz.*). *Bangladesh Journal of Botany*, *48*(1), 75-84.

Singh, S. (2007). Role of management practices on control of isoproturon-resistant little seed canary grass (*Phalaris minor*) in India. *Weed Technology*, *21*(2), 339−346.

Singh, S., Kirkwood, R. C. and Marshall, G. (1997). Effects of isoproturon on photosynthesis in susceptible and resistant biotypes of *Phalaris minor* in wheat. *Weed Research*, *37*, 315-324.

Singh, S., Kirkwood, R. C. and Marshall, G. (1998). Effect of monooxygenase inhibitor piperonyl butoxide on herbicidal activity and metabolism of isoproturon in resistant biotypes of *Phalaris minor*. *Pesticide Biochemistry Physiology*, *59*(3), 143−153.

Singh, S., Malik, R. K., Balyan, R. S. and Singh, S. (1995). Distribution of weed flora of wheat in Haryana. *Indian Journal of Weed Science*, *27*(3&4), 114−121.

Tardif, F. J. and Powles, S. B. (1999). Effect of malathion on resistance to soil-applied herbicides in a population of rigid ryegrass (*Lolium rigidum*). *Weed Science*, *47*(3), 258-261.

Wrubel, R. P. and Gressel, J. (1994). Are herbicide mixtures useful for delaying the rapid evolution of resistance? A case study. *Weed Technology*, *8*(3), 635-648.

Yadav, A. and Malik, R. K. (2005). Herbicide resistant *Phalaris minor* in wheat-A sustainability issue. Resource Book. Department of Agronomy and Directorate of Extension Education, CCSHAU, Hisar, India. P.152.

Yasuor, H., Osuna M. D., Ortiz, A., Saldaín N. E., Eckert, J. W. and Fischer, A. J. (2009). Mechanism of resistance to penoxsulam in late watergrass [*Echinochloa phyllopogon* (Stapf) Koss]. *Journal of Agricultural and Food Chemistry*, *57*(9), 3653–3660.

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