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The impact of various herbicide combinations on weed flora in wheat crops in the Gird region of Madhya Pradesh

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Abstract
The present investigation entitled "The impact of various herbicide combinations on weed flora in wheat crops in the Gird region of Madhya Pradesh" was conducted during *rabi* season of 2022-23 and 2023-24 at agronomy research farm of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.). The soil of experiment was sandy clay loam with low aggregation, neutral in reaction (pH 7.43), low in organic carbon (0.45%), medium in available nitrogen (182 kg ha^{-1}), medium in available phosphorus (13.5 kg ha^{-1}) and high in available potassium (220 kg ha^{-1}) The experiment was carried out in a Randomized block design with eight treatments and three replications. The treatment comprises of W1- Weed free (two hand weeding 30 and 45 DAS), W2- Post- Emergence application of Pyroxasulfone 85% WG @ 127.5 g/ha, W3- Post-Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha, W4- Early Post- Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha, W5- Post -Emergence application of Metribuzin 70% WP @ 300 g/ha, W6-Post-Emergence application of Clodinafop propargyl 9% + Metribuzin 20% WP @ 600 g/ha, W7-Post-emergence application Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop propargyl 15 WP @ 60 g/ha and W8-Weedy check (without herbicide treatment). The highest number of individuals was recorded in both year for *Cyprus rotendus* (28.33 & 27.33%), *Medicago denticulata* (19.67% & 19.34%), *Chenopodium album* (18.00% & 17.00%), *Phalaris minor* (17.33% & 17.00%), and *Convolvulus arvensis* (16.34% & 15.33%). All the herbicide treatments provided significant control of weeds causing significant reduction in density of target weed flora and improved the grain yield compared with the weedy check. The highest mortality of weeds (90.15%) and higher values of growth parameters, yield attributes and maximum wheat grain yield was recorded where post-emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha was applied.

Keywords: Herbicide treatments, hand weeding, weed flora, yield attributes, wheat grain, growth perameters, pyroxasulfone, metsulfurone

Introduction

Wheat (*Triticum aestivum*) is the widely cultivated staple food crop of the world. It is grown 219.61 million ha with a production of 729.10 million tonnes in the world (FAO, 2016) [7]. Currently, India is the second largest producer of wheat in the world after China. In India, it is cultivated in 30.23 million hectares area with the production of 93.50 million tonnes. Madhya Pradesh, contributes 17.50 and 18.92% to the total area and production of wheat in the country but the productivity is far below (2993 kg ha^{-1}) the northern states (Agricultural Statistics, 2016) [1].

A formidable factor that limits its productivity is severe weed competition, as weeds competes with crop plants for water, nutrients, space and solar radiation, resulting in reduction of yield to the tune of 29 per cent (Pandey *et al*., 2006) [19]. Manual removal of weeds in wheat crop is laborious, time consuming and uneconomical due to higher labour requirement and wages. Henceforth, mechanical method of weed control is not common in wheat and chemical method is commonly used to get rid of weeds (Montazeri *et al*., 2005) [17]. However, dependency on herbicides having similar mode of action is also not advisable as it lead to shift in weed flora and rapid evolution of cross and multiple resistance in weeds (Singh, 2007) [23]. Presently, farmers are using tank mixture herbicides in wheat but such herbicide mixtures when used at higher rates cause phytotoxicity on wheat crop also. On the contrary, in ready-mix formulations the different herbicides are mixed in optimum concentration at the time of manufacturing to avoid any phytotoxicity on the crop. The use of ready-mix formulations is advantageous over sequential applications due to saving in time and cost. Ready-mixtures, besides providing effective control of complex weed flora also helps in managing as well as delaying the herbicide resistance in weeds (Wruble and Gressel, 1994) [29]. The field efficacy of ready-mix formulation of clodinafop 15% + metsulfuron 1% (Vesta) provides effective control of mixed weed flora in wheat (Malik *et al*., 2013) [14]. Like-wise ready-mixture formulation of sulfosulfuron 75% + metsulfuron 5% (Total/Satasat) also gives excellent control of resistant population of *Phalaris minor* and broad-leaved weeds (Punia *et al*., 2013) [22].

Weed infestation is one of the main causes of low wheat yield not only in India but all over the world, as it reduces wheat yield by 37-50% (Waheed *et al*. 2009) [25]. Rice-wheat is one of the most important cropping systems in northern part of the country. The Phalaris minor is one of the very serious problems in wheat in this cropping system and sometimes almost 65% crop losses have been reported (Chhokar *et al*. 2008) [6]. Broad-leaved weeds (BLWs) are also causing a threat, but their management is comparatively easier and effective, whereas, control of *Phalaris minor* has become a serious challenge. Chemical weed control is a preferred practice due to scare and costly labour as well as lesser feasibility of mechanical or manual weeding in wheat.

The judicious management of weed plays an important role in enhancing wheat productivity. Weeds growing in association with irrigated and heavy fertilized crop decline its yield by 15-40 per cent or even higher besides lowering down the quality of produce by way of weed seed contamination (Yadav *et al*., 2006) [30]. Therefore, weed management is a basic requirement and major component of crop production system (Young *et al*., 1996) [31]. However, weeding has never been a priority due to a variety of reasons. Weeds can be controlled manually which is laborious, time consuming, costly, energy intensive and it is only possible on small scale. Mechanical means are economical but it controls only inter - row weeds, not intra - row weeds. In such situations, herbicides offer most ideal, practically effective and economical means of reducing early weed competition and crop production losses. So, chemical method of controlling weeds is most effective, efficient, up-to-date and time saving (Ashiq *et al*., 2007) [3].

Regular use of the same herbicide year after year has led to problem of herbicide resistance. The sole dependence on herbicide of single mode of action is also not advisable as it has contributed to shift towards difficult to control weeds and rapid evolution of multiple herbicides resistance, which is a threat to wheat production (Singh, 2007) [23]. The herbicide, isoproturon and pendimethalin are being used for the last two decades for weed control in wheat. (Walia *et al*., 1998) [26]. Combination of grassy and broad leaf weed herbicides was better than their separate application for weed control in wheat (Cheema and Akhtar, 2005) [5]. this study assessed the herbicidal effects on weed flora, growth parameters and grain yield.

Pyroxasulfone is a relatively new herbicide (pre-emergence or post-emergence). It has been approved for use in corn, soybean, cotton, and wheat in a number of countries. Pyroxasulfone's herbicidal efficacy was evaluated using growth inhibition tests, greenhouse tests, and a field trial. Pyroxasulfone herbicide demonstrated excellent herbicidal activity at lower application rates than S-metolachlor and has sufficient residual activity, making it an effective tool for chemical weed management programmes.

Materials and Methods

A field experiment was conducted during two consecutive *Rabi* seasons of year 2022-23 and 2023-24 at Research Farm, Department of Agronomy, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (MP.). Gwalior is situated at 26°22' North latitude and 78°18' East longitudes with an altitude of 197 meters above the mean sea level. The seedbed was prepared by ploughing the field with a disc harrow, followed by one pass with a field cultivator and two plankings. The wheat variety "GW 322" was sown manually on 28 November 2022 and 21 November 2023 (both year experiment) using a seed rate of 100 kg ha^{-1} in 20 cm spaced rows. The seeds were treated before sowing with vitavex 2.5 g kg^{-1} of seed to make them free from seed-borne diseases. The experiment comprised of eight treatments consisting different weed control chemicals like Pyroxasulfone 85% WG, Metsulfurone 20% WP, Clodinafoppropargyl 15% WP, Metribuzin 20% WP, Clodinafoppropargyl 9% + Metribuzin 20% WP (ready mix) with two hand weeding (30 and 45 DAS), and weedy check were assigned in a randomized block design with three replications (Table 1). The texture of the soil of the experimental field was sandy clay loam with low aggregation. It was medium in organic carbon (0.45%), available nitrogen (182 kg N ha^{-1}), and available phosphorus (13.5 kg P_20_5 ha^{-1}) but high in available potassium (220 kg K_20 ha^{-1}). The soil was nearly neutral in reaction (7.43 pH), and the concentration of soluble salts (0.26 ds m^{-1}) was below the harmful limit. The crop was given a recommended dose of fertilizers, i.e.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. Irrespective of herbicide dosage, it was sprayed as post-emergence 25 (early post-emergence) and 30 (post-emergence) days after sowing of wheat. Before spraying, the measured amount of herbicide and water for each plot was well mixed. Herbicides were administered to the plots with a backpack sprayer equipped with a flat fan nozzle. Each time, a new solution was prepared for each plot separately. Observations on plant growth and yield were recorded, and economics was calculated after that. The analysis of variance (ANOVA) method was used for statistical analysis in standard statistical software, and a comparison of treatment means was made for a 5% level of significance using critical differences (CD) (Gomez and Gomez, 1984) [9]. The weed density of weeds was recorded at different crop stages by using quadrant of 50 x 50 cm. The crop was raised with recommended agronomic and plant protection techniques. Data weed density of weeds were subjected to log transformation (log x) before statistical analysis. Weed control efficiency (WCE) and Weed index was calculated by using the following formula suggested by Mani *et al.* (1968) [15], Gill and Kumar (1969) [8]. and expressed in percentage:

$$WCE = \frac{DMC - DMT}{DMC} \times 100$$

Where,

DMC is the dry matter of weeds in the control (unweeded) plot

DMT is the dry matter of weeds in the treated plot.

$$WI = \frac{X - Y}{X} \times 100$$

Where

WI = Weed index

X = Seed yield of weed free plot
Y = Seed yield of the treated plot for which weed index is to be worked out

Table 1: Treatment details of experiments

S. no	Treatment	Treatment Symbol
1	Weed Free (hand weeding 30 & 45 DAS)	W1
2	Post- Emergence application of Pyroxasulfone 85% WG @ 127.5 g/ha	W2
3	Post-Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha	W3
4	Early Post- Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha	W4
5	Post -Emergence application of Metribuzin 70% WP @ 300 g/ha	W5
6	Post-Emergence application of Clodinafop propargyl 9% + Metribuzin 20% WP @ 600 g/ha	W6
7	Post-emergence application Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop propargyl 15 WP @ 60 g/ha	W7
8	Weedy check	W8

Results and Discussion

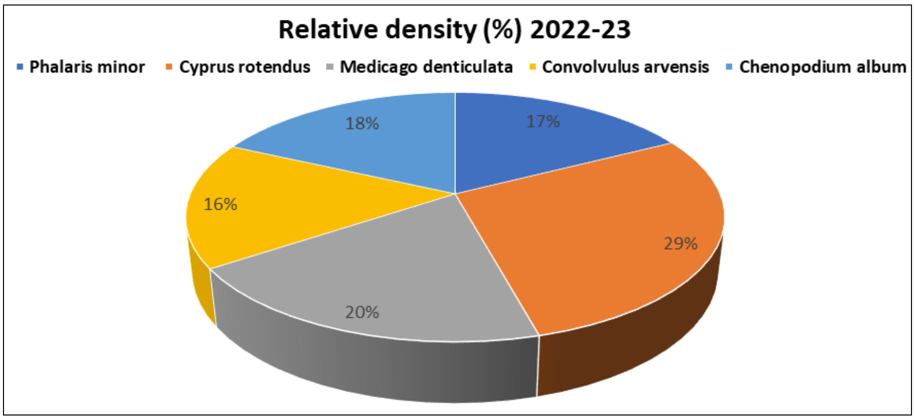
The experimental field was absolutely invaded with mixed population of weed flora consisting of both dicots and monocots. Among the total weeds, dicots in both years (54.19% and 53.82%) were more prominent than monocot weeds (45.81% and 46.18%). Major dicot weed flora during *Rabi* season in wheat crop was dominated by *Chenopodium album, Medicago denticulata* and *Convolvulus arvensis* and among the monocots weeds *Cyperus rotundus*, and *Phalaris minor* were the weeds observed in the experimental field (Table 2 and fig.1). Herbicide treatments showed differences in weed control during both the years of experimentation in wheat crop. Similar observations on weed flora in wheat was also reported by Khobragade and Sathawane (2014) [11].

Table 2: Species wise weed density and relative density of associated weeds in weedy check plots at 60 DAS in wheat during *Rabi* seasons (2022-23 and 2023-24)

Weed flora	Common name	Family	Weed density (m^{-2})		Relative density (%)	
			2022-23	2023-24	2022-23	2023-24
Monocot						
Phalaris minor	canary grass	Poaceae	17.33	17.00	17.39	17.71
Cyprus rotendus	Nutgrass	Cyperaceae	28.33	27.33	28.42	28.47
	Sub- total		45.66	44.33	45.81	46.18
Dicots						
Medicago denticulata	Toothed bur clover	Fabaceae	19.67	19.34	19.74	20.14
Convolvulus arvensis	Bindweed	Convolvulace	16.34	15.33	16.39	15.97
Chenopodium album	lambsquarter	Chenopodiaceae	18.00	17.00	18.06	17.71
		Sub - total	54	51.67	54.19	53.82
		Grand total	99.67	96.00	100	100

Effect on weed density and dry weight of weeds

Pooled analysis of data revealed significant reduction in all weed control treatments with respect to weed density and dry weed biomass over unweeded control as indicated in (Table 3 and 4). Highest reduction in weed density and dry matter of weeds at 60 DAS were recorded under two hand weeding (11.67 weeds/m^2, 3.28 g/m^2) due to complete removal of the weeds among the herbicides, Post-Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha was found to be more superior in curtailing the weed population and dry weight of weeds (37.67 weeds/m^2, 6.90 g/m^2) followed by Post-emergence application Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop propargyl 15 WP @ 60 g/ha (39.17 weeds/m^2, 8.57 g/m^2) as compared to unweeded control (Table 3 & 4). Sole application of a single herbicide was less effective in controlling weeds as compared to their pre-mix application. The tank mixtures of broad-leaf and grassy weed killing herbicides provided higher order of performance in terms of weed density and intensity of total weeds as observed by Meena *et al*. (2017) [16]. Pre-mix combination of post-emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha provided excellent control of weeds. Total weed population was reduced significantly due to various weed control treatments. This might be due to the herbicidal application alone and in combination which were effective in timely reducing total weed population. Lekh Chand and Punia (2017) [13] also reported similar results.



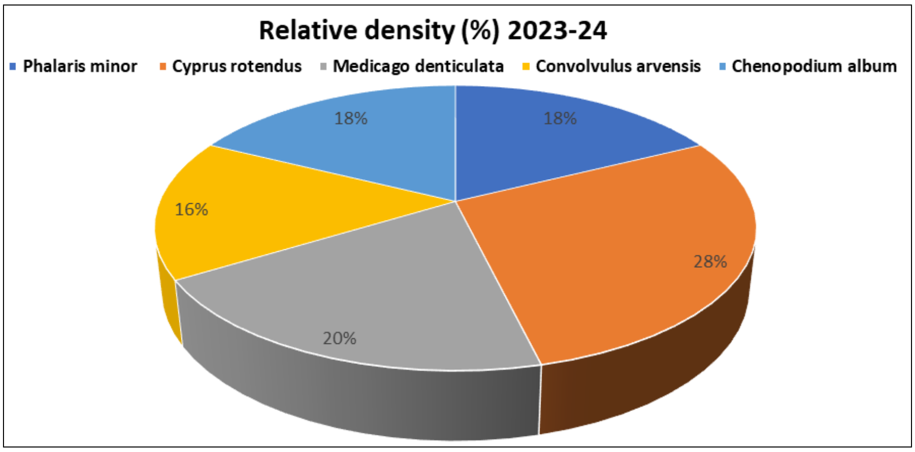


Fig 1: Relative density (%)

Table 3: Effect of different weed control treatments on total weed density at 60 DAS

	Treatment	Dose (g *a.i.* ha^{-1})	Weeds (m^{-2}) (60 DAS)		
			2022-23	2023-24	Pooled
T_1	Weed Free (two hand weeding 30 & 45 DAS)	twice	1.10 (12.67)	1.03 (10.67)	1.07 (11.67)
T_2	Post- Emergence application of Pyroxasulfone 85% WG @ 127.5 g/ha	127.5	1.90 (79.67)	1.90 (79.00)	1.90 (79.33)
T_3	Post-Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha	127.5+4	1.57 (37.33)	1.58 (38.00)	1.58 (37.67)
T_4	Early Post- Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha	127.5+4	1.63 (43.00)	1.66 (45.33)	1.64 (44.17)
T_5	Post -Emergence application of Metribuzin 70% WP 300 g/ha	300	1.75 (56.33)	1.76 (57.33)	1.75 (56.83)
T_6	Post-Emergence application of Clodinafop propargyl 9% + Metribuzin 20% WP @ 600 g/ha	600	1.64 (44.00)	1.66 (45.67)	1.65 (44.83)
T_7	Post-emergence application Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop propargyl 15 WP 60 g/ha	4+60	1.59 (38.67)	1.60 (39.67)	1.59 (39.17)
T_8	Weedy check	-	2.00 (99.67)	1.98 (96.00)	1.99 (97.83)
	Sem+-		0.007	0.009	0.006
	CD(P=0.05)		0.021	0.0266	0.0162

Data subjected to log x transformation. Figures in parentheses are means of original values.

Table 4: Effect of different weed control treatments on total dry weight at 60 DAS (pooled of two years)

	Treatment	Dose (g *a.i.* ha^{-1})	Dry weight (g) at 60 DAS		
			2022-23	2023-24	Pooled
T_1	Weed Free (two hand weeding 30 & 45 DAS)	twice	3.15	3.40	3.28
T_2	Post- Emergence application of Pyroxasulfone 85% WG @ 127.5 g/ha	127.5	39.60	37.40	38.50
T_3	Post-Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha	127.5+4	6.75	7.04	6.90
T_4	Early Post- Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha	127.5+4	11.66	13.39	12.53
T_5	Post -Emergence application of Metribuzin 70% WP 300 g/ha	300	24.00	22.59	23.30
T_6	Post-Emergence application of Clodinafop propargyl 9% + Metribuzin 20% WP @ 600 g/ha	600	11.74	10.84	11.29
T_7	Post-emergence application Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop propargyl 15 WP 60 g/ha	4+60	7.73	9.40	8.57
T_8	Weedy check	-	72.50	67.50	70.00
	Sem+-		0.593	0.660	0.444
	CD(P=0.05)		1.800	2.001	1.285

Effect on weed control efficiency and weed index

Based on pooled analysis of data result showed that the weed control efficiency in wheat was significantly influenced by weed management treatments, where all the treatments resulted in increase of weed control efficiency over the weedy check. Highest value of weed control efficiency (95.32%) was obtained from hand weeding treatment. Amongst herbicides, maximum value of WCE was achieved by post-emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha (90.15%) followed by post-emergence application Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop propargyl 15 WP @ 60 g/ha (87.76%) application of pre-emergence herbicides while sole application of single herbicides registered low weed control efficiency (Table 5 and fig.2). This indicate that pre-mix herbicides have significant effect on minimizing the weed population, which resulted increased yield over control treatment. Similar results were also reported by Kumar *et al.* (2022) [12] with Pyroxasulfone + Metsulfuron in wheat. The lowest weed index (1.78%) was obtained with post-emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha followed by post-emergence application Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop propargyl 15 WP @ 60 g/ha (2.82%). Whereas yield reduction varied from 1.78% to 37.5% in the herbicide applied plots as compared to weed free treatment (Table 5 and fig.2). Weed index was lower in all the treatments as compared to weedy check. which provided favourable conditions for crop growth which ultimately increased the grain yield of wheat crop as compared to weedy check treatment. Similar trends in weed control efficiency and weed index were also recorded by Kumar *et al.* (2022) [12].

Table 5: weed control efficiency and weed index (pooled of two years)

	Treatment	Dose (g a.i. ha^{-1})	WCE (%) at 60 DAS			WI (%)		
			2022-23	2023-24	Pooled	2022-23	2023-24	pooled
T_1	Weed Free (two hand weeding 30 & 45 DAS)	twice	95.66	94.96	95.32	0.00	0.00	0.00
T_2	Post- Emergence application of Pyroxasulfone 85% WG @ 127.5 g/ha	127.5	45.38	44.59	45.00	19.04	19.37	19.21
T_3	Post-Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha	127.5+4	90.69	89.57	90.15	1.71	1.85	1.78
T_4	Early Post- Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha	127.5+4	83.92	80.16	82.10	3.15	6.43	4.79
T_5	Post -Emergence application of Metribuzin 70% WP 300 g/ha	300	66.89	66.53	66.72	12.38	15.07	13.73
T_6	Post-Emergence application of Clodinafop propargyl 9% + Metribuzin 20% WP @ 600 g/ha	600	83.81	83.95	83.88	2.85	5.87	4.36
T_7	Post-emergence application Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop propargyl 15 WP 60 g/ha	4+60	89.34	86.07	87.76	2.59	3.05	2.82
T_8	Weedy check	-	0.00	0.00	0.00	36.51	38.49	37.50

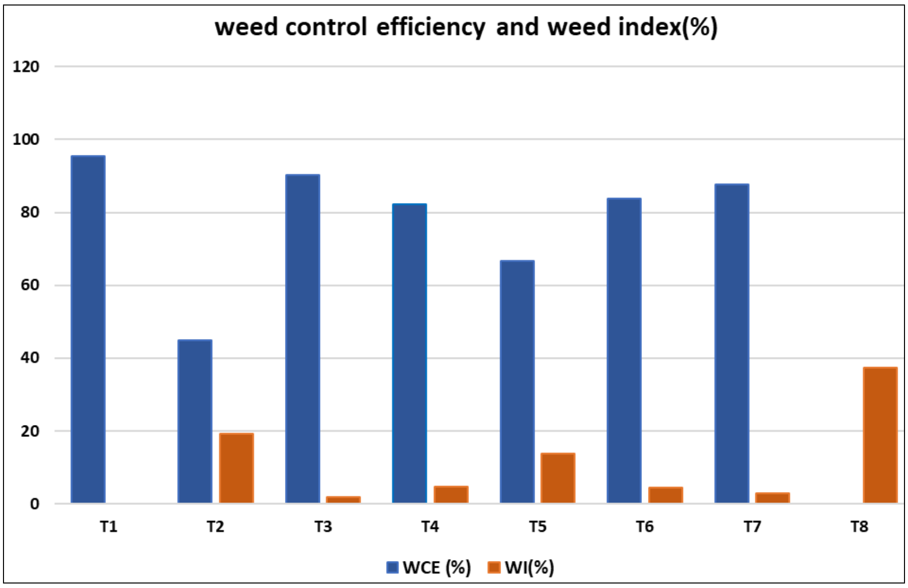


Fig 2: weed control efficiency and weed index (pooled of two years)

Effect on crop growth and yield

Based on pooled analysis of data, our results revelled significant reduction in plant height in unweeded control treatment which might be due to competition between crop and weeds for soil moisture, plant nutrients, solar radiation and space during active growth period (Table 6). These results were in accordance with the results reported by Pradhan and Chakraborti (2010) [21]. Significantly the highest number of effective tillers meter^{-1} row length was recorded in two hand weeding treatment (84.20 tillers meter^{-1} row length) but remained at par with all treatments where pre-mix combination of post-emergence herbicides were sprayed i.e. post-emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha, post-emergence application Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop propargyl 15 WP @ 60 g/ha. Data on grain per spike at harvest showed significant differences among treatments and showed the similar trends as in case of other growth attributes (Table 6). These results in accordance with the results reported by Amare *et al.* (2014) [2] and Kumar *et al.* (2022) [12].

Table 6: Growth and yield attributes of wheat as influenced by weed control treatments (pooled of two years)

	Treatment	Dose (g a.i. ha^{-1})	Plant height at harvest (cm)			No. of effective tillers m^{-1} row length			No. of grains per spike		
			2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	Weed Free (two hand weeding 30 & 45 DAS)	twice	91.56	91.17	91.37	83.80	84.60	84.20	42.21	42.14	42.18
T_2	Post- Emergence application of Pyroxasulfone 85% WG @ 127.5 g/ha	127.5	85.36	85.28	85.32	78.60	81.00	79.80	38.24	38.00	38.12
T_3	Post-Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha	127.5+4	90.88	90.56	90.72	82.40	84.00	83.20	41.50	41.20	41.35
T_4	Early Post- Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha	127.5+4	87.38	87.08	87.23	81.20	83.60	82.40	41.30	41.00	41.15
T_5	Post -Emergence application of Metribuzin 70% WP 300 g/ha	300	84.22	84.78	84.50	79.20	81.40	80.30	39.24	38.70	38.97
T_6	Post-Emergence application of Clodinafop propargyl 9% + Metribuzin 20% WP @ 600 g/ha	600	86.52	87.26	86.89	81.40	83.00	82.20	41.45	41.00	41.23
T_7	Post-emergence application Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop propargyl 15 WP 60 g/ha	4+60	89.33	88.92	89.13	82.00	83.40	82.70	41.37	42.60	41.99
T_8	Weedy check	-	81.34	82.07	81.70	67.20	64.80	66.00	35.10	34.68	34.89
	S.Em+-		1.330	1.004	0.834	1.312	1.430	0.970	0.580	0.652	0.436
	CD(P=0.05)		3.895	2.941	2.405	3.981	4.337	2.810	1.760	1.979	1.264

Table 7: Grain yield, straw yield and biological yield as influenced by weed control treatments in wheat (pooled of two years)

	Treatment	Dose (g *a.i.* ha^{-1})	Grain yield			straw yield			Biological yield		
			2022-23	2023-24	Pooled	2022-23	2023-24	pooled	2022-23	2023-24	pooled
T_1	Weed Free (two hand weeding 30 & 45 DAS)	twice	5908	6004	5956	8124	8234	8179	14032	14238	14135
T_2	Post- Emergence application of Pyroxasulfone 85% WG @ 127.5 g/ha	127.5	4783	4841	4812	7261	7510	7386	12044	12351	12198
T_3	Post-Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha	127.5+4	5807	5893	5850	8250	8354	8302	14057	14247	14152
T_4	Early Post- Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha	127.5+4	5722	5618	5670	7849	7950	7900	13571	13568	13570
T_5	Post -Emergence application of Metribuzin 70% WP 300 g/ha	300	5177	5099	5138	7800	7700	7750	12977	12799	12888
T_6	Post-Emergence application of Clodinafop propargyl 9% + Metribuzin 20% WP @ 600 g/ha	600	5740	5652	5696	8001	7900	7951	13741	13552	13646
T_7	Post-emergence application Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop propargyl 15 WP 60 g/ha	4+60	5755	5821	5788	8058	8356	8207	13813	14177	13995
T_8	Weedy check	-	3751	3693	3722	6720	6500	6610	10471	10193	10332
	S.Em+-		101.21	90.27	67.81	89.46	122.82	75.98	187	104	107
	CD(P=0.05)		307.02	273.84	196.40	271.38	372.58	220.05	569	314	310

Pooled analysis of different weed control treatments registered significant increase in grain yield of wheat compared to unweeded control during all the two years of study. Two hand weeding at 30 and 45 DAS recorded highest grain yield of 5956 kg/ha. Further data explicated that collective application of herbicides either as pre-mix, tank mix or sequentially gave significantly higher yield over single applied herbicides. Among the herbicides, higher value of grain yield in individual years and in pooled data was obtained with post-emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha (5850 kg/ha.) closely followed by post-emergence application Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop propargyl 15 WP @ 60 g/ha (5788 kg/ha) (Table 7). Pooled data showed that both these treatments recorded 36.37% and 36.76% increase in grain yield over unweeded control was due to higher growth and yield attributes due to reduced weed infestation by these treatments, which helped the crop plants to accumulate more dry matter through more nutrient uptake that might have provided more quantity of photosynthates to developing sink in crop plants resulted in more yield. Similar results of improvement grain yield and weed control has been reported by Walia *et al.* (2010) [27] and Chaudhari *et al.* (2017) [4] with different herbicides combinations. Next best treatments in order of merit regarding the grain yield were post-emergence application of Clodinafop propargyl 9% + Metribuzin 20% WP @ 600 g/ha and Early Post- Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha, which brought about 34.65% and 34.35% increase in grain yield in both years over unweeded control. The solitary application of single herbicide resulted in lesser grain yield compared to pre-mix combination of post-emergence herbicides.

Conclusion

Based on the findings of a two-year investigation, it can be concluded that an effective weed management strategy in irrigated wheat involves the post-emergence application of Pyroxasulfone 85% WG + Metsulfuron 20% WG at 127.5 + 4 g/ha. This combination demonstrated superior control of complex weed flora, leading to a significant improvement in crop health and productivity. The application of these herbicides combination effectively suppressed both grass and broadleaf weed species, reducing weed competition and ensuring better nutrient availability for the wheat crop. Therefore, for sustainable wheat production in irrigated conditions, the post-emergence application of Pyroxasulfone 85% WG + Metsulfuron 20% WG at the recommended rate should be strongly considered as an integral component of integrated weed management (IWM) programs.

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