



The Influence of Different Post-emergence Herbicide Mixtures on the Physiological Traits and Yield of Irrigated Wheat (*Triticum aestivum* L.) in Madhya Pradesh, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation was conducted during the *rabi* season of 2022-23 and 2023-24 at the agronomy research farm of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.). The experiment was carried out in a Randomized block design with eight treatments and three

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replications. The values of LAI, CGR and AGR were increasing up to 90 DAS and RGR upto 60 DAS growth stage and then declined upto maturity. Among the weed control treatments, the highest values of LAI, CGR, RGR and AGR were recorded under weed free plot which was followed by post-emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha and post-emergence application Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop propargyl 15 WP @ 60 g/ha at almost all the crop growth stage. The results indicated that the combined application of post-emergence Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha significantly enhanced plant height, leaf area and dry matter production, followed by the post-emergence application of Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop Propargyl 15 WP @ 60 g/ha. These treatments performed better than the control and were statistically comparable to the weed-free plot.

The highest grain yield, straw yield and harvest index was recorded in the weed-free plot, while the lowest yield was observed in the weedy check plot. However, the combined application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha resulted in grain yield, straw yield and harvest index statistically similar to the weed-free plot, demonstrating its effectiveness in controlling weeds and enhancing crop productivity.

Keywords: *Weed control; hand weeding; weed flora; yield attributes; wheat grain; physiological traits; pyroxasulfone; leaf area index (LAI); crop growth rate (CGR); relative growth rate (RGR); and absolute growth rate (AGR).*

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is the widely cultivated staple food crop of the world. It is grown in an area of 217.02 million hectares with a production of 765 million metric tons in the world. In India, it is grown in an area of 31.45 million hectares with a production of 107.592 million metric tons and productivity of 3420 kg per hectare (USDA., 2020). In Madhya Pradesh, wheat is grown in a 6.5 million hectares area with a production of 16.52 million metric tons and productivity of 3298 kg per hectare (Department of Agriculture., M.P. 2020; Potter & James, 1977).

“Weed infestation is one of the major barriers to realizing potential yield of wheat. Uncontrolled weeds are reported to cause up to 66% reduction in wheat grain yield” (Angiras, et al., 2008; Olsen et al., 1954)

“Weed infestation is a major bottleneck to higher productivity under late-sown wheat that competes with crops for water, nutrients, space, light and release of allelochemicals into the rhizosphere” (Khaliq, et al., 2014). “Wheat crop is badly infested with grass as well as broad-leaf weeds. All types of weeds are not controlled by a single herbicide and the continuous use of the same herbicide results in weed shifts and the evolution of herbicide resistance. The use of integrated chemical control measures is needed for effective control of mixed weed flora. Continuous use of isoproturon for control of *Phalaris minor* resulted

in the development of resistance in wheat. Now, *Phalaris minor* has evolved multiple resistance against fenoxaprop, clodinafop and sulfosulfuron” (Singh, et al., 2010; Piper, 1967).

“Wheat is one of the most important crops of India, not only in terms of acreage but also in terms of its versatility for adoption under a wide range of agro-climatic conditions and crop growing situations. Wheat is also used for manufacturing bread, flakes, cakes, biscuits etc. It is produced in a wide range of climatic environments and geographic regions” (Dixon, et al., 2009). “Due to rising demographic pressure, it becomes necessary to augment the productivity of food crops, including wheat, continuously to ensure food security” (Swaminathan & Bhawani., 2013; Jackson, 1967).

“The five major wheat-growing states are Uttar Pradesh, Punjab, Madhya Pradesh, Haryana, and Rajasthan contributed nearly 86.0 percent of the total production in the country. Punjab has the highest average productivity of 4.70 t ha⁻¹, followed by Haryana (4.40 t ha⁻¹). Rajasthan accounted for about 10.71 percent (3.10 MHA) of the national area and 11.10 percent (10.46 MT) of grain production with an average productivity of 3.1 t ha⁻¹ (Commission for Agricultural Costs and Prices., 2019). Weeds adversely affect crop growth and yield by competing with crops for limiting resources such as light, water, and nutrients” (Harper, 1977, Swanton, et al., 2015).

“The intensity and duration of the crop-weed competition determines the magnitude of crop yield losses” (Swanton, et al., 2015). “Uncontrolled growth of weeds, on average, caused about a 48 percent reduction in the grain yield of wheat when compared with weed-free conditions” (Singh, et al., 2012). “Herbicides play an important role in weed control in closely spaced crops like wheat and barley, where manual or mechanical weeding is difficult” (Yadu & Das, 2002). “Among different weed management practices, chemical weed control is preferred because of less labor involvement and no mechanical damage to the crop that happens during manual weeding” (Marwat, et al., 2008). These necessitate evolving a strategy to screen out more herbicides to control the weed flora economically in the wheat fields on a large scale. In India, herbicides share only about 8 percent of total pesticide consumption in the country and we use an average of only about 35-gram herbicides ha⁻¹ annum⁻¹ (Gupta, 2007; Singh et al., 2017).

“Post-emergence herbicide mixtures are commonly used to target a broad spectrum of weed species while minimizing crop injury” (Hager, 2019). “However, the application of these herbicides can also affect the physiological traits of wheat, including photosynthetic efficiency, chlorophyll content, stomatal conductance, and oxidative stress response” (Sharma, et al., 2021; Subbiah & Asija, 1956).

“Among various factors responsible for low yield, weed infestation, and nutrient management are of supreme importance. Weed competes with crop plants for water, nutrients, space, and solar radiation resulting in a reduction of yield by 40.3%” (Bharat, et al., 2012). “Cultural, mechanical, and chemical methods are commonly used for controlling weeds. Chemical weed control is an important alternative. Herbicides are beneficial and very effective means of controlling weeds in wheat because they are quite effective and efficient” (Azad, et al., 1997).

“Some herbicide mixtures may induce phytotoxic effects, leading to reduced LAI, CGR, RGR, and AGR, ultimately impacting grain yield and quality. Conversely, well-balanced herbicide mixtures may provide effective weed control with minimal adverse effects on wheat growth” (Kudsk & Mathiassen., 2020, Sharma, et al., 2016).

Despite the widespread use of post-emergence herbicides, limited research exists on their

specific impact on LAI and growth indices in irrigated wheat systems. Understanding these effects is crucial for optimizing herbicide application strategies to maximize weed control while maintaining crop productivity. Therefore, this study aims to evaluate the influence of different post-emergence herbicide mixtures on the physiological and growth responses of irrigated wheat, focusing on key parameters such as LAI, CGR, RGR, and AGR.

2. MATERIALS AND METHODS

A field experiment was conducted in the Gird region of M.P. during two consecutive *Rabi* seasons of the year 2022-23 and 2023-24 at Research Farm, Department of Agronomy, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.). Gwalior is situated at 26°22' North latitude and 78°18' East longitude 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 experiments) using a seed rate of 100 kg ha⁻¹ in 20 cm spaced rows. The seeds were treated before sowing with Vitavax 2.5 g kg⁻¹ of seed to make them free from seed-borne diseases. The experiment comprised eight treatments consisting of different Chemical herbicides 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 P₂O₅ ha⁻¹) but high in available potassium (220 kg K₂O 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 P₂O₅, and 40 kg K₂O ha⁻¹ through urea, single super phosphate, and murate of potash, respectively. All herbicides are 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 (Walkey & Black, 1934). 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 & Gomez, 1984). The physiological growth parameters are calculated by using the following equations.

2.1 Leaf Area Index (LAI)

The leaf area index expresses the ratio of the leaf surface to the ground area occupied by the plant. It was calculated to find out the influence of various treatments on the assimilatory surface area of the plant. The leaf area was recorded by using a leaf area meter (model LI 300) at different growth stages (30, 60 and 90 DAS) and then the leaf area index was worked out by using the formula given by (Watson, 1952, Laxorov,1965).

$$\text{Leaf area index} = \frac{A}{P}$$

Where,

- A = Leaf area (cm²)
- P = Ground area (cm²)

2.2 Crop Growth Rate (g m⁻² day⁻¹)

The gain in weight of a community of plants in a unit land area in a unit of time is termed as crop growth rate and expressed in g m⁻² day⁻¹. It was

2.5 Harvest Index (HI)

It is the ratio expressed in percentage of economic yield about biological yield. It was estimated by the formula proposed by (Nichiporovich, 1967).

$$\text{Harvest index (HI)} = \frac{\text{Economic yield (grain)}}{\text{Biological yield (straw + grain)}} \times 100$$

calculated as per the following formula suggested by (Potter and James., 1977).

$$\text{CGR (g m}^{-2} \text{ day}^{-1}) = \frac{W_2 - W_1}{(T_2 - T_1) P}$$

Where,

W₁ and W₂ are dry matter and at time t₁ and t₂, respectively. P represents the ground area.

2.3 Relative Growth Rate (g g⁻¹ day⁻¹)

It is expressed as the dry weight increase in a time interval about the initial weight. The mean relative growth rate is calculated from measurement at times t₁ and t₂ and expressed as g g⁻¹ day⁻¹ (Beadle, 1985).

$$\text{RGR (g g}^{-1} \text{ day}^{-1}) = \frac{\text{Loge}W_2 - \text{Loge}W_1}{(T_2 - T_1)}$$

Where,

W₁ and W₂ are dry matter and at time t₁ and t₂ respectively

2.4 Absolute Growth Rate (g day⁻¹)

AGR was calculated from total dry matter accumulation by using the formula given by (Radford, 1967) and expressed as g/day/plant.

$$\text{AGR (g day}^{-1}) = \frac{W_2 - W_1}{(T_2 - T_1)}$$

W₂ and W₁ are the mass of the plant at time t₂ and t₁, respectively.

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

S. no	Treatment	Treatment Symbol
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 @ 60g/ha	W7
8	Weedy check	W8

3. RESULTS AND DISCUSSION

3.1 Effects of Weed Control Treatments

The growth parameters, plant height, and number of leaves per plant, as well as dry matter production were significantly influenced by weed control treatments at all crop growth stages except 30 DAS. Combined application of post-emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha and post-emergence application Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop propargyl 15 WP @ 60 g/ha were found most effective herbicides to enhance the plant height and leaf area per plant as well as dry matter production and all these were comparable to weed free treatment (Table 2). This may also be because the plants under less crop-weed competition had more vertical and horizontal growth; as a result, these treatments recorded more plant height and leaf area and dry matter production as compared to other treatments. These results also corroborate the findings of (Ahmed & Tarique., 2010, Pradhan & Chakraborti., 2010, Sharma et al., 2016).

Weed management practices had a significant impact on Leaf Area Index (LAI), Crop Growth Rate (CGR), Relative Growth Rate (RGR), and Absolute Growth Rate (AGR) at different growth stages (Table 3). Among these parameters, LAI, CGR, and AGR showed an increasing trend up to 90 DAS (Days After Sowing). At the same time, RGR increased up to 60 DAS before declining due to leaf senescence, aging and complex physiological processes in the plant. The LAI increased from 30 to 90 DAS but declined from 90 DAS to maturity due to natural aging and reduced leaf activity. The highest values 4.94, 6.11 and 2.12 at 60, 90 DAS and maturity, respectively of LAI, was recorded in weed-free check, while the lowest were observed in unweeded control. Among the herbicides, the application of 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 and

post-emergence application of Clodinafop propargyl 9% + Metribuzin 20% WP @ 600 g/ha resulted in higher values for LAI at 60, 90 DAS and maturity stages. A similar result was also obtained by (Chahal, et al., 2003, Sharma, et al., 2016). The present investigation indicated that all these combined herbicidal treatments effectively controlled narrow as well as broad leaf weeds at 60 DAS and harvest stages and thus helped the wheat crop to grow better with higher leaf expansion, finally resulting in higher values for leaf area index. The reduction in the LAI in rice due to weed competition was also observed by (Noda, et al.,1968).

The Crop Growth Rate (CGR) was significantly influenced by different weed control treatments at all growth stages except at 30 DAS. The highest CGR values 33.83, 35.17, and 15.73 g m⁻² day⁻¹ were recorded in the weed-free plot at 30-60 DAS, 60-90 DAS and maturity, respectively. In contrast, the lowest CGR values 18.33, 18.00, and 6.13 g m⁻² day⁻¹ were observed in the unweeded control at the corresponding growth stages.

Among the herbicidal treatments, the post-emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha and Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop Propargyl 15 WP @ 60 g/ha resulted in CGR values statistically similar to those in the weed-free plot at all growth stages. The increased CGR in these treatments may be attributed to reduced weed competition and a higher Leaf Area Index (LAI), which enhanced photosynthetic efficiency and dry matter accumulation. These findings are consistent with the results of (Kumar, et al., 2003).

The Relative Growth Rate (RGR) was observed to be lower during the early stages of crop growth, increasing up to 60 days after sowing (DAS) and subsequently declining toward the maturity stage. These findings align with those of (Shukla & Warsi, 2000), who reported that wheat exhibited its maximum RGR between 30 and 60 DAS. Weed control treatments significantly influenced this parameter, particularly at 60 DAS.

Table 2. Effect of different post-emergence herbicide mixtures on plant height, leaf area, and dry matter production of wheat at successive crop growth stages (pooled basis)

Treatments	Dose (g a.i. ha ⁻¹)	Plant height (cm)				Leaf area(cm ²)				Dry matter production(g)			
		30DAS	60DAS	90DAS	Maturity	30DAS	60DAS	90DAS	Maturity	30DAS	60DAS	90DAS	Maturity
T ₁ Weed Free (two hand weeding 30 & 45 DAS)	twice	14.39	55.47	89.81	91.37	71.60	197.60	244.40	84.80	1.23	5.29	9.51	11.87
T ₂ Post- Emergence application of Pyroxasulfone 85% WG @ 127.5 g/ha	127.5	13.96	51.04	84.86	85.32	70.60	156.80	182.80	66.60	1.19	3.94	7.13	8.45
T ₃ Post-Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha	127.5+4	14.18	54.23	89.39	90.72	71.60	191.80	233.00	84.00	1.21	5.17	9.24	11.39
T ₄ Early post-emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha	127.5+4	14.32	53.39	86.39	87.23	71.40	170.19	223.20	79.60	1.20	5.01	8.88	10.80
T ₅ Post -Emergence application of Metribuzin 70% WP @ 300 g/ha	300	14.00	52.27	84.09	84.50	71.40	165.40	203.40	73.00	1.20	4.18	7.49	9.00
T ₆ Post-Emergence application of Clodinafop propargyl 9% + Metribuzin 20% WP @ 600 g/ha	600	13.90	53.17	86.50	86.89	71.80	179.60	223.80	82.40	1.21	5.06	9.07	11.18
T ₇ Post-emergence application Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop propargyl 15 WP @ 60g/ha	4+60	14.13	54.35	88.16	89.13	70.20	188.40	226.80	83.20	1.21	5.12	9.21	11.33
T ₈ Weedy check	-	14.30	38.56	80.62	81.70	70.60	127.43	152.80	51.40	1.20	3.40	5.56	6.48
Sem+-		0.134	0.533	0.710	0.834	0.80	3.24	2.45	0.74	0.01	0.050	0.101	0.097
CD(P=0.05)		NS	1.539	2.048	2.405	NS	9.40	7.10	2.13	NS	0.144	0.293	0.281

Table 3. Effect of different post-emergence herbicide mixtures on LAI, AGR, CGR and RGR of wheat at successive crop growth stages (pooled basis)

Treatment	Dose (g a.i. ha ⁻¹)	LAI				AGR (g day ⁻¹)			CGR (g m ⁻² day ⁻¹)			RGR (mg g ⁻¹ day ⁻¹)		
		30DAS	60DAS	90DAS	maturity	30-60	60-90	maturity	30-60	60-90	maturity	30-60	60-90	maturity
T ₁ Weed Free (two hand weeding 30 & 45 DAS)	twice	1.79	4.94	6.11	2.12	0.1353	0.1407	0.0621	33.83	35.17	15.73	48.63	19.55	5.83
T ₂ Post- Emergence application of Pyroxasulfone 85% WG @ 127.5 g/ha	127.5	1.77	3.92	4.57	1.67	0.0917	0.1063	0.0347	22.92	26.58	8.80	39.91	19.77	4.47
T ₃ Post-Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha	127.5+4	1.79	4.80	5.82	2.10	0.1320	0.1357	0.0566	33.00	33.92	14.33	48.41	19.36	5.51
T ₄ Early post-emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha	127.5+4	1.79	4.26	5.58	1.99	0.1270	0.1289	0.0505	31.75	32.25	12.80	47.64	19.08	5.15
T ₅ Post -Emergence application of Metribuzin 70% WP @ 300 g/ha	300	1.79	4.14	5.09	1.83	0.0993	0.1103	0.0397	24.83	27.58	10.07	41.60	19.44	4.83
T ₆ Post-Emergence application of Clodinafop propargyl 9% + Metribuzin 20% WP @ 600 g/ha	600	1.80	4.49	5.60	2.06	0.1285	0.1337	0.0555	32.13	33.42	14.07	47.83	19.45	5.50
T ₇ Post-emergence application Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop propargyl 15 WP @ 60g/ha	4+60	1.76	4.71	5.67	2.08	0.1303	0.1363	0.0558	32.58	34.08	14.13	48.09	19.57	5.45
T ₈ Weedy check	-	1.77	3.19	3.82	1.29	0.0733	0.0720	0.0242	18.33	18.00	6.13	34.71	16.39	4.03
Sem+-		0.02	0.09	0.10	0.02	0.0013	0.0014	0.0005	0.44	0.28	0.16	0.40	0.16	0.04
CD(P=0.05)		NS	0.27	0.30	0.06	0.0038	0.0041	0.0014	1.28	0.815	0.45	1.16	0.45	0.11

Table 4. Effect of different post-emergence herbicide mixtures on grain yield, straw yield and harvest index of wheat

Treatment	Dose (g a.i. ha ⁻¹)	Grain yield(kg/ha)			Increase in yield (%)	Straw yield(kg/ha)			Harvest index (%)		
		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	60.02%	8124	8234	8179	42.10	42.17	42.14
T ₂ Post- Emergence application of Pyroxasulfone 85% WG @ 127.5 g/ha	127.5	4783	4841	4812	29.28%	7261	7510	7386	39.71	39.20	39.45
T ₃ Post-Emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha	127.5+4	5807	5893	5850	57.17%	8250	8354	8302	41.31	41.36	41.34
T ₄ Early post-emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha	127.5+4	5722	5618	5670	52.33%	7849	7950	7900	42.16	41.41	41.79
T ₅ Post -Emergence application of Metribuzin 70% WP @ 300 g/ha	300	5177	5099	5138	38.04%	7800	7700	7750	39.89	39.84	39.87
T ₆ Post-Emergence application of Clodinafop propargyl 9% + Metribuzin 20% WP @ 600 g/ha	600	5740	5652	5696	53.03%	8001	7900	7951	41.77	41.71	41.74
T ₇ Post-emergence application Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop propargyl 15 WP @ 60g/ha	4+60	5755	5821	5788	55.50%	8058	8356	8207	41.66	41.06	41.36
T ₈ Weedy check	-	3751	3693	3722	-	6720	6500	6610	35.82	36.23	36.03
Sem+-		101.21	90.27	67.81	-	89.46	122.82	75.98	0.76	0.69	0.51
CD(P=0.05)		307.02	273.84	196.40	-	271.38	372.58	220.05	2.29	2.09	1.48

The highest RGR values 48.63, 19.55, and 5.83 mg g⁻¹ day⁻¹ were recorded in the weed-free plot at 30-60 DAS, 60-90 DAS and maturity, respectively. In contrast, the lowest RGR values 34.71, 16.39, and 4.03 mg g⁻¹ day⁻¹ were observed in the unweeded control at the same growth stages. The post-emergence application of Pyroxasulfone 85% WG + Metsulfuron 20% WG @ 127.5 + 4 g/ha recorded RGR values statistically similar to those of all tank-mix, pre-mix, and sequential herbicide treatments. The improved RGR in these treatments can be attributed to the effective control of both narrow and broadleaf weeds, reducing competition for essential resources such as nutrients, water, and light.

The Absolute Growth Rate (AGR) increased from 30 to 90 DAS and then declined from 90 DAS to the maturity stage. The highest AGR values 0.1353, 0.1407, and 0.0621 g day⁻¹ were recorded in the weed-free plot at 30-60 DAS, 60-90 DAS and maturity, respectively. In contrast, the lowest AGR values 0.0733, 0.0720, and 0.0242 g day⁻¹ were observed in the unweeded control at the corresponding growth stages. This indicates that weed competition significantly hinders dry matter production, reducing the efficiency of plant growth.

Among the herbicidal treatments, the post-emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha, Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop Propargyl 15 WP @ 60 g/ha, and Clodinafop Propargyl 9% + Metribuzin 20% WP

@ 600 g/ha were found to be highly effective. These treatments resulted in statistically identical AGR values to those recorded in the weed-free plot, highlighting their efficiency in controlling weed interference and promoting plant growth. Similar results were also reported by (Sharma, et al., 2016).

All herbicidal treatments significantly increased yield and yield components like grain yield, straw yield and harvest index over weedy check. The highest grain (5956 kg/ha) and straw yield (8179 kg/ha) were recorded in weed-free plots, while the minimum was in the weedy check. Among the herbicides, post-emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG @ 127.5 + 4 g/ha recorded significantly higher grain as well as straw yield and were at par with weed-free plots during both years. However, pre-mix application of, post-emergence application Metsulfurone Methyl 20% WP @ 4 g/ha + Clodinafop propargyl 15 WP @ 60g/ha and sequential application of post-emergence application of Clodinafop propargyl 9% + Metribuzin 20% WP @ 600 g/ha were also statistically at par with weed-free plot in respect of straw yield kg/ha (Table 4).

The highest harvest index (42.14%) was recorded in the weed-free plot, while the lowest was observed in the weedy check (36.03%). Among the herbicidal treatments, the post-emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG at 127.5 + 4 g/ha resulted in a significantly higher harvest index, which was statistically at par with the weed-free

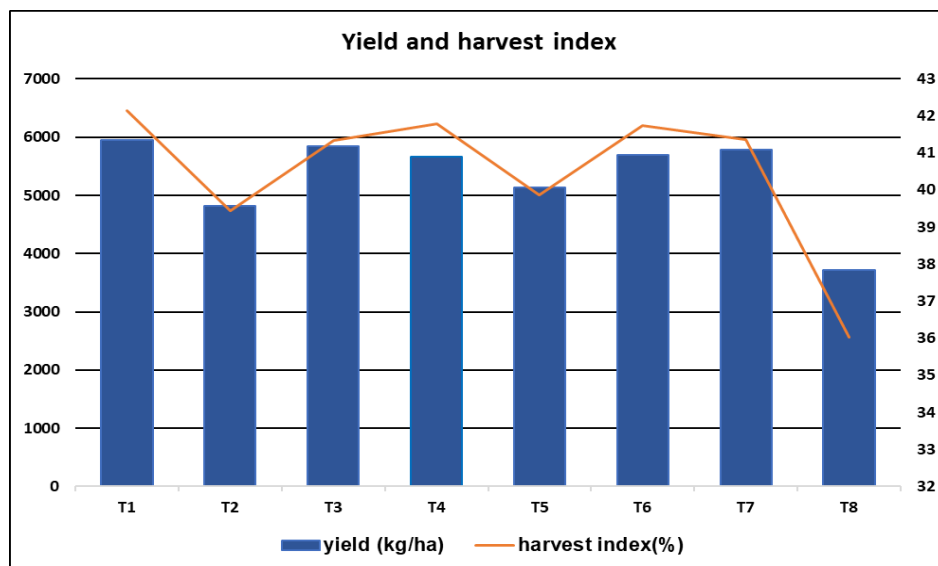


Fig. 1. Yield and harvest index (pooled of two years)

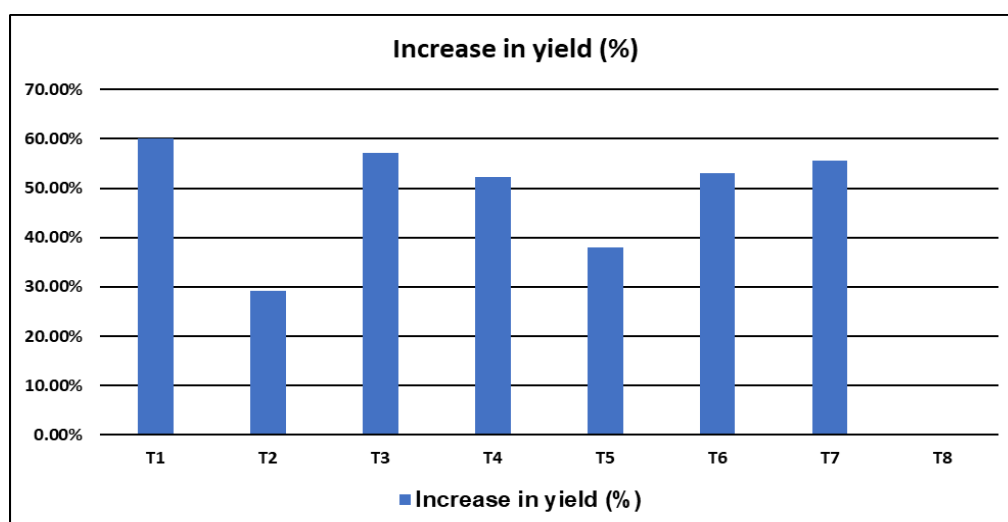


Fig. 2. Grain yield increasing percentage compared to weedy check (pooled of two years)

plot in both years of the study (Table 4 & Fig. 1). A similar result was also obtained by (Choudhary, et al., 2016). Such superior treatments minimized weed-crop competition and saved more available environmental resources for crop plants that improved growth traits. This, in turn, increased leaf area index, and plant height and produced more assimilates synthesized, translocated and accumulated in various plant organs, which positively reflected on grain and straw yield/ha. Application of, 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 @ 60g/ha, 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. Increased grain yield by 57.17, 55.50, 53.03 and 52.33 percent, respectively as compared to the weedy check. At the same time, weed-free plots increased grain yield by 60.02 percent over the weedy check (Table 4 & Fig. 2). The superiority of these treatments over weedy check in increasing yield has also been reported by (Sharma, et al., 2016, Shoeron, et al., 2013).

4. CONCLUSION

Based on a two-year investigation, it is concluded that the post-emergence application of Pyroxasulfone 85% WG + Metsulfurone 20% WG at 127.5 + 4 g/ha followed by hand weeding proved to be the most effective weed control treatment. This approach resulted in superior

crop dry matter accumulation, improved physiological parameters, higher grain yield (5956 kg/ha), and an enhanced harvest index in wheat compared to other weed control treatments.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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