**The influence of different post-emergence herbicide mixtures on the physiological traits of irrigated wheat (Triticum aestivum L.).**

**Abstract**

The present investigation entitled **“The influence of different post-emergence herbicide mixtures on the physiological traits of irrigated wheat (*Triticum aestivum* L.).”** 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 values of LAI, CGR and AGR were increasing up to 90 DAS and RGR upto 60 DAS growth stage and then decline 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, LAI, CGR, RGR, 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 hectare with the production of 765 million metric tons in the world. In India, it is grown in an area of 31.45 million hectare with production of 107.592 million metric tons and productivity of 3420 kg per hectare (USDA, 2020). In Madhya Pradesh, wheat is grown in 6.5 million hectares area with the production of 16.52 million metric tons and productivity of 3298 kg per hectares (Department of Agriculture, M.P. 2020).

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 wide range of agro-climatic conditions and crop growing situations. Wheat is also used for manufacturing of bread, flakes, cakes, biscuits etc. It is produced in wide range of climatic environments and geographic regions (Dixon *et al*., 2009). It provides 21 percent of the food calories and 20 percent of protein for 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 wide range of agro-climatic conditions and crop growing situations. Wheat is also used for manufacturing of bread, flakes, cakes, biscuits etc. It is produced in wide range of climatic environments and geographic regions (Dixon *et al.,* 2009). It provides 21 percent of the food calories and 20 percent of protein for more than 4.5 billion people in 94 developing countries (Braun *et al.,* 2010). Due to rising demographic pressure, it become necessary to augment the productivity of food crops including wheat on continues basis to ensure food security (Swaminathan and Bhawani, 2013).

The five major wheat growing states of Uttar Pradesh, Punjab, Madhya Pradesh, Haryana and Rajasthan contributed nearly 86.0 per cent 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 per cent (3.10 mha) of the national area and 11.10 per cent (10.46 MT) of grain production with average productivity of 3.1 t ha-1 (Commission for Agricultural Costs and Prices, 2019). Weeds adversely affect the 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 an average caused about 48 per cent reduction in grain yield of wheat when compared with weed free condition (Singh *et al*., 2012). Herbicides play an important role for weed control in closely spaced crops like wheat and barley, where manual or mechanical weeding is difficult (Yadu Raju and Das, 2002). Among different weed management practices, chemical weed control preferred because of less labour 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 large scale. In India, herbicide shares only about 8 per cent of total pesticide consumption in country and we use an average of only about 35-gram herbicides ha-1 annum-1 (Gupta, 2007).

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). Some herbicide mixtures may induce phytotoxic effects, reducing crop growth and yield potential, while others may show a synergistic effect, improving weed control with minimal impact on wheat physiology (Kudsk & Mathiassen, 2020).

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 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. Herbicide have shown to be beneficial and very effective means of controlling weeds in wheat because they are quite effective and efficient (Azad *et al.,* 1997).

Post-emergence herbicide mixtures are widely used in wheat production to control weed infestations. While effective in reducing weed competition, herbicide application can also affect wheat physiology by influencing photosynthesis, chlorophyll content, stomatal conductance, and oxidative stress responses (Sharma *et al.,* 2021). 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).

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.

1. **Material 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 (M.P.). 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 P205 ha-1) but high in available potassium (220 kg K20 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. 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). The physiological growth parameters are calculated by using the following equations.

* 1. **Leaf area index (LAI)**

The mean was computed. After this, total leaf area per plant was worked out by multiplying the mean leaf area with number of leave plant-1. LAI is the leaf area (A) or the assimilatory surface area over a certain ground area (P) and was calculated by the formula given by (Gardner *et al*., 1985)

|  |  |
| --- | --- |
| Leaf area index = | A |
| P |

Where,

A = Leaf area (cm2)

P = Ground area (cm2)

* 1. **Crop growth rate (g m-2 day-1)**

The gain in weight of community of plant in a unit land area in a unit time is termed as crop growth rate and expressed in g m-2 day-1. It was calculated as per the following formula suggested by (Potter and James, 1977).

|  |  |
| --- | --- |
| CGR (g m-2 day-1) = | W2-W1 |
| (T2-T1) P |

Where,

W1, W2 are dry matter and at time t1, 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 in relation to the initial weight. The mean relative growth rate is calculated from measurement at time t1 and t2 and expressed as g g-1 day-1 (Beadle, 1985).

|  |  |
| --- | --- |
| RGR (g g-1 day-1) = | LogeW2 - LogeW1 |
| (T2-T1) |

Where,

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

* 1. **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.

|  |  |
| --- | --- |
| AGR (g day-1) = | W2-W1 |
| (T2-T1) |

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

* 1. **Harvest index (HI)**

It is the ratio expressed in per centage of economic yield in relation to biological yield. It was estimated by the formula proposed by (Nichiporovich, 1967).

|  |  |  |
| --- | --- | --- |
| Harvest index (HI) = | Economic yield (grain) | ×100 |
| Biological yield (straw +grain) |

**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 @ 60g/ha | **W7** |
| 8 | **Weedy check** | **W8** |

1. **RESULTS AND DISCUSSION**
   1. **Effects of weed control treatments**

The growth parameters, plant height and number of leaves per plant as well as dry matter production was 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 due to the fact that 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 with the finding of (Ahmed and Tarique, 2010), (Pradhan and chakraborti, 2010) and (*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), while 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 was 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 similar result was also obtained by (Chahal *et al*., 2003)*, (Sharma et al.,2016)*. The present investigation clearly indicated that all these combined herbicidal treatments effectively controlled narrow as well as broad leaf weeds at 60 DAS and harvest stages and thus helps 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 the (Noda *et al.,*1968).

**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(cm2)** | | | | **Dry matter production(g)** | | | |
| **30** | **60** | **90** | **Maturity** | **30** | **60** | **90** | **Maturity** | **30** | **60** | **90** | **Maturity** |
| **T1** | **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 |
| **T2** | 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 |
| **T3** | 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 |
| **T4** | 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 |
| **T5** | 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 |
| **T6** | 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 |
| **T7** | 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 |
| **T8** | **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** |

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 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 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 and 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.

The highest RGR values 48.63, 19.55, and 5.83 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 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 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 were observed in the unweeded control at the corresponding growth stages. This clearly 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

**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)** | | |
| **30** | **60** | **90** | **maturity** | **30-60** | **60-90** | **maturity** | **30-60** | **60-90** | **maturity** | **30-60** | | **60-90** | **maturity** |
| **T1** | **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 |
| **T2** | 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 |
| **T3** | 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 |
| **T4** | 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 |
| **T5** | 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 |
| **T6** | 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 |
| **T7** | 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 |
| **T8** | **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** |

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) recorded in weed free plot while minimum in 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 plot during both the 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 plot in both years of the study (Table 4 & Fig 1). 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 plant that improved growth traits. This in turns increased leaf area index, plant height and produced more assimilates synthesized, translocated and accumulated in various plants 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 weedy check. Whereas, weed free plot increasing grain yield by 60.02 percent over 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) and (Shoeron *et al*.,2013).

**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** |
| **T1** | **Weed Free** (two hand weeding 30 & 45 DAS) | **twice** | 5908 | 6004 | 5956 | 60.02% | 8124 | 8234 | 8179 | 42.10 | 42.17 | 42.14 |
| **T2** | 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 |
| **T3** | 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 |
| **T4** | 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 |
| **T5** | 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 |
| **T6** | 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 |
| **T7** | 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 |
| **T8** | **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** |

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

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

1. **Conclusion**

Based on a two-year investigation, it is concluded that the **pre-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.

**REFERENCES**

Ahmed F and Tarique M H. 2010.Effect of herbicides on the yield and yield components of wheat. International J. of Sustainable Agricultural Technology. 6(3) 27-30.

Azad B S, Singh H and Gupta S C.1997.Effect of plant density, dose of herbicide and time of nitrogen application on weed suppression and its efficiency in wheat (L.). Env Ecol. (3) 665-668.

Beadle C Z. 1985. Plant growth analysis. The techniques in bio reductivity and photosynthesis by Coombs JC, Hall DP, Lang SP and Scarlo CO, JMO Pergamon press, p 20-25.

Bharat Rajeev, Kachroo Dileep, Sharma Rohit, Gupta M. and Sharma Anil Kumar 2012. Effect of different herbicides on growth and yield performance of wheat. Indian Journal of weed Science. (2) 106-109.

Braun, H J., Atlin, G. and Payne, T. 2010. Multi location testing as a tool to identify plant response to global climatic change. In: Climate Change and Crop Production CABI, London, Unnited Kingdom- 8-9.

Chahal P S, Brar H S and Walia US. 2003. Management of Phalaris minor in wheat through integrated approach Indian Journal of Weed Science. (1/2) :1-5.

Choudhary, D., Singh, P. K., Chopra, N. K., & Rana, S. C. (2016). Effect of herbicides and herbicide mixtures on weeds in wheat. Indian Journal of Agricultural Research, *50*(2), 107-112.

Commissionerate of Agriculture, Crop-wise Area, Production and Yield of various principal crops Second Advance Estimates of *Kharif* 2019 & First Advance Estimates of *Rabi* 2019-20, Rajasthan–Jaipur

Dixon, J., Braun, H.J. and Crouch, J.H. 2009. Overview: Transitioning wheat research to serve future needs of developing world. In: Wheat Facts and Futures CYMMIYT, Mexico pp- 1-25

Gardner F P, Pearcer R B and Mitchell R L. 1985. Growth and development in physiology of crop plants. The Iowa State University Press, IA, USA. pp 187-208.

Gomez K A and Gomez A A, 1984. Statistical procedures for agricultural Research. An international rice research institute book, A Wiley-Inter science, John Wiley and Sons Inc. New york, USA.

Gupta, O P, 2007. Modern weed management. Third revised edition. Agribios (India) Publication.pp-130, Appendix 11.

Hager, A. 2019. Herbicide interactions: Understanding synergism and antagonism in weed control. Weed Science Society of America Journal, 67(2), 129-140.

Harper, J I. 1977. The population biology of plants. Academic Press, London, UK.

[https://ipad.fas.usda.gov/search.aspx USDA.2020](https://ipad.fas.usda.gov/search.aspx%20USDA.2020). World agriculture production.

Jackson ML. 1967. Soil chemical analysis. Prentice Hall, India Private Limited, New Delhi. pp 183-192.

Kudsk, P., & Mathiassen, S. K. 2020. Optimizing herbicide use: Effects of mixtures and application timing. Weed Research, 60(3), 209-222.

Kumar Deep, Angiras N N, Singh Y and Rana, S S. 2003. Influence of seed manipulations and herbicides on leaf area index and growth rate of wheat and associated weeds. Himachal Journal of Agricultural Research. 29(1&2) :1-10.

Marwat, K. B., Mahammad, S., Zahid, H., Gul, B. and Rashid, H. 2008. Study of various weed management practices for weed control in wheat under irrigated conditions. Pakistan Journal of Weed Science Research 14 (1-2): 1-8.

Nichiporovich A A 1967. Aims of research on the photosynthesis of plants as a factor of production. In photosynthesis of productive system programme for Science Translation, Jerusalam, Israel. pp 3-36.

Noda K, Ozarva K and akari 1968. Studies on the damage to rice plant due to competition. Bulletin Kyushy Agriculture Experiment Station. 13:345-361.

Olsen S R, Cole C V, Watnable F S and Dean L A. 1954. Estimation of available phosphorus in soils by extraction with HNO3. In diagnosis and improvement of saline and alkaline soils. USDA Handbook No. 60.

Piper C S. 1967. Soil and plant analysis. Asia Publication House, Bombay. pp 157-176.

Potter J R and J W James. 1977. Leaf area partitioning as an important factor in growth. Plant physiology 59: 10-14.

Pradhan A C, and Chakraborti Prabir. 2010.Quality wheat seed production through integrated weed management. Indian Journal of Weed Science. 42(3/4): 159-162.

Radford, P J 1967 Growth analysis formulae their use and abuse. Crop Science. 7(3):171 175.

Sharma J, Tomer S S, Rajput R L, Prajapati B L, & Yadav S. 2016. Effect of fertility levels and weed management practices on physiological growth parameter of irrigated wheat. International Journal of Agriculture & Horticulture Sciences,7(3):633-637

Sharma, N., Singh, S., & Gupta, R. K. 2021. Physiological and biochemical responses of wheat to herbicide stress: A review. *Plant Physiology Reports, 26*(1), 23-38.

Shoeron Suman, Punia S S, Yadav Ashok and Singh Samunder. 2013. Bioefficacy of pinoxaen in combination with other herbicides against complex weed flora in wheat. Indian Journal of Weed Science.45 (2): 90-92.

Shukla S K, and Warsi A S. 2000. Effect of sulpher and micronutrients on growth, nutrient content and yield of wheat (*Triticum aestivum* L.). Indian Journal of Agricultural Research. 34(3): 203-205.

Singh R., Singh P. Singh V K., Singh V P. and Pratap T. 2012. Effect of different herbicides on weed dry matter and yield of wheat. International Agronomy Congress 2: 138-139.

Singh V P, Barman K K, Singh P K, Singh R, Dixit A. 2017 Managing weeds in rice (*Oryza sativa*)-wheat (*Triticum aestivum*)-greengram (*Vigna radiata*) system under conservation agriculture in black cotton soils. Indian Journal of Agricultural Sciences. 87:739-45

Subbiah B V and Asija G L. 1956. A rapid procedure for the estimation of available nitrogen in soils. Current Science 2:259-260.

Swaminathan, M S. and Bhavani, R V. 2013. Food production and availability – Essential prerequisites for sustainable food security. Indian Journal of Medicinal Research, 138: 383-391.

Swanton C J. Nkoa, R. and Blackshaw, R.E. 2015. Experimental methods for crop weed competition studies. Weed Science 63(1): 2-11.

Walkey A and Black C A. 1934. An experimentation of the delayreff method for determining organic matter of the chromic acid titration method. Journal of Agricultural Science 37:29-38.

Yaduraju, N.T. and Das, T.K. 2002. Bioefficacy of metsulfuron- methyl and 2, 4-D on Canada thistle. Indian Journal of Weed Science 34(1&2):110-111.