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# Comparative Efficacy of Different Herbicidal Combinations on Weed Growth and Yield Attributes of Wheat

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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

Weeds are the main biotic obstacles on wheat production, which can impair wheat productivity by up to 60%, if not handled under critical stages of crop life cycle. Chemical weed control through herbicides has been the most popular and effective method among farmers. The weed management using similar herbicides however has led to herbicide resistance in weeds. This requires the evaluation of newer herbicidal combinations for the control of weeds in wheat. Therefore, an experiment was conducted at Research Farm, Department of Agronomy, JNKVV, Jabalpur, Madhya Pradesh during the *Rabi* season of 2016-17 to evaluate the effect of post emergence application of herbicides on the weeds and yield of wheat. The experiment was laid out in randomized block design with ten treatments comprising of eight herbicidal combinations along

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with a hand weeding and a weed check and replicated thrice. Observations on different weed parameters, growth parameters and yield of wheat were recorded. Among the different herbicidal combinations, the post emergence application of halauxifen-methyl ester + florasulam at 10.20 g/ha resulted in greatest suppression of weeds and had highest weed control efficiency (56.73%). It also led to highest growth in wheat which resulted in highest grain yield (5.81 t/ha) and harvest index (44.99%). From this study, it can be concluded that the post emergence application of halauxifen-methyl ester + florasulam at 10.20 g/ha can not only control weeds effectively but also increase the yield of wheat.

*Keywords: Florasulam; grain yield; halauxifen-methyl ester; harvest index; weed control efficiency; wheat.*

## 1. INTRODUCTION

"Wheat (*Triticum aestivum* L.) is one of the most important cereal crops occupying the prime position among food crops in the world" [1]. "It is the most significant grain crop, both historically and as a source of human nourishment" [2]. "In India, it is the second important food crops being next to the rice. Wheat is a staple food for over one billion people in 43 nations around the world. It accounts for around 20% of total dietary calories consumed by humans" [3]. "Wheat is farmed on around 220 million hectares worldwide, with approximately half of that area in developing nations. In 2019–20, wheat was grown in India on an area of about 31.45 million hectares with a production of 107.59 million tonnes" [4]. "In Madhya Pradesh, wheat is produced on about 10.02 million hectares, producing 16.52 million tonnes of grain with a productivity of 3298 kg/ha" [5]. Hence, it is important to increase the yield of wheat particularly in irrigated areas of Madhya Pradesh.

There are many factors which is affected crop output under changing climatic conditions [6,7] but one of the formidable factors that limit the crop productivity is severe weed infestation [8,9]. "Weeds have a habit to shift with the alteration in tillage, agronomic management, and cropping system although there are other factors that govern the alterations in the weed flora" [10,11]. "Although being a serious problem in crop field, this problem always remains under-estimated although they cause higher reduction in economic yield of crops than other pests and diseases" [12,13]. "Weeds are a major barrier to maintaining wheat production and productivity levels" [14,15]. "The critical period of crop weed competition in wheat crop is 11- 21 days after crop emerged [16] and reduction of grain yield in late sown wheat was reported up to 34.3% due to mixed weed flora" [17].

"Manual weed control is regarded as the best and sustainable weed management option; however, increasing costs and labour shortage have rendered this technique ineffective" [18,19]. "Hiking costs of manual weed control have forced farmers to adopt alternative weed management strategies" [20,21]. "Weed management with herbicides is an easiest and most successful method" [22,23]. "Herbicides have played a significant role in modern agriculture for weed management" [24,25]. "Thus, for sustainable weed control, adopting herbicide application techniques may be an effective and economic weed control strategy" [26,27]. "Many herbicides are being used for effective control of weeds in wheat but their weed control efficacy is affected to great extent by the climatic condition at the time of application of almost all herbicides whether applied as pre emergence or post emergence" [28]. "In such a crisis, herbicides with different modes of action, such as pendimethalin (pre-emergence) and metribuzin (pre-emergence or post-emergence) alone and in sequential or tank mix combination with post-emergence herbicides sulfosulfuron and clodinofop, pinoxaden, could be viable options" [29]. Metsulfuron and Sulfosulfuron are the most widely used herbicides in wheat for effective control of weeds but sometimes they have not been effective due to resistance to weeds. Hence, the present investigation was proposed to compare the new post emergence herbicides i.e. halauxifen-methyl ester + florasulam with the existing ones to find out the best herbicidal combination for controlling diverse weed flora of wheat.

## 2. MATERIALS AND METHODS

A field experiment was carried out at the Research Farm, Department of Agronomy, JNKVV, Jabalpur, Madhya Pradesh during the *Rabi* season of 2016-17. Soil of the experimental area is clayey in texture, neutral in reaction

**Table 1. Physio-chemical properties of the soil in the experimental field**

| S. No. | Particular | Values | Class/Groups | Method used |
|---|---|---|---|---|
| **A.** | **Mechanical composition** | | | |
| 1. | Sand (%) | 25.189 | Clay | International pipette method |
| 2. | Silt (%) | 19.18 | | [30] |
| 3. | Clay (%) | 55.64 | | |
| **B.** | **Chemicals compositions** | | | |
| 1. | Organic carbon (%) | 0.64 | Medium | Walkey and Black rapid titration Method [31] |
| 2. | Available N (kg/ha) | 370 | Medium | Alkaline permanganate method [32] |
| 3. | Available P (kg/ha) | 16 | Medium | Calorimetric method [33] |
| 4. | Available K (kg/ha) | 298 | High | Flame photometer method [34] |
| 5. | Soil PH (1:2:5 Soil water ratio) | 7.3 | Neutral | Glass electrode pH meter [30] |
| 6. | Electrical conductivity (ds/m at 25 °C) | 0.32 | Normal | Sole-Bridge method [35] |

(pH 7.3), medium in organic carbon content (0.64%), normal in electrical conductivity (0.32 ds/m), medium in available N (370.0 kg/ha), available P (16.0 kg /ha) and high in available K (298 kg/ha). Physio-chemical Properties of the soil are given in Table 1. Ten treatments consisted with post emergence application of halauxifen-methyl ester + florasulam at 7.6 g/ha ($T_1$), halauxifen-methyl ester + florasulam at 10.20 g/ha ($T_2$), halauxifen-methyl ester + florasulam at 12.70 g/ha ($T_3$), halauxifen-methyl ester + florasulam at 25.50 g/ha ($T_4$) and mesosulfuron + Iodosulfuron at 14.40 g/ha ($T_5$), sulfosulfuron + metsulfuron methyl at 32.0 g/ha ($T_6$), metsulfuron + clodinafop propargyl at 10.00 g/ha ($T_7$), metsulfuron-methyl at 4 g/ha ($T_8$) along with a hand weeding ($T_9$) and weedy check($T_{10}$), were tested in randomized block design with three replications. Sowing of the experiment was done on December 1, 2016 in 5.00 x 3.60 m plot size with seed rate of 100 kg/ha by drilling in rows 22.5 cm apart. A uniform dose of 120 kg N, 60 kg $P_20_5$ and 40 kg $K_20$/ha was given in the experimental plots through urea, single super phosphate and muriate of potash, respectively. Five irrigation were given to the crop at all the critical stages viz., crown root initiation, maximum tillering, late jointing, flowering and milk stage. Different studies were made during the course of investigation pertaining to weed and crop parameters. The quadrat of 0.25/$m^2$ (0.5 m x 0.5 m) was randomly thrown at four places in each plot and then it was marked by fixing wooden stick for subsequent observation. Species wise weed count and total number of weeds per meter square were recorded. The percentage composition of weed flora was estimated from weedy check. Growth parameters viz. plant height, tillers/$m^2$ were recorded at 60 DAS. Yield attributing characters viz., grains/ear head was recorded. Harvesting was done when the panicle matured and plant was dried up. The threshing of the crop was done manually plot-wise and grain and straw were collected separately. The grain yield was recorded as kg/plot and then converted into t/ha.

## 3. RESULTS AND DISCUSSION

### 3.1 Effect on Weeds

In the experimental field, dominated weeds viz. *Phalaris minor, Medicago denticulate*, *Cichorium intybus, Chenopodium album, Anagalis arvensis* and *Convolvulus arvensis* were found. Similar weed species were also reported by Sahu et al. [36], Patel et al. [37].

Weed control treatments had significant influence on the weed density and dry weight during the course of filed experimentation (Tables 2 & 3). The density and dry weight of predominant weeds were found maximum under weedy check plots due to uninterrupted growth of weeds from germination up to the end of critical period of crop-weed competition (i.e. 45 DAS) [38]. But the density of predominant weeds and their dry weight reduced identically in plots receiving either herbicidal or mechanical weed control. The post emergence application of halauxifen-methyl ester + florasulam at 10.20 g/ha curbed the weed growth to that of significant reduction in broadleaf weeds as well as grassy followed by halauxifen-methyl ester + florasulam at 7.6 g/ha and halauxifen-methyl ester + florasulam at 10.2 g/ha after the 60 days of application of former herbicides [39]. These herbicides gave satisfactory control of both the broad leaved

weeds and annual grassy weed was better control weed like *Phalaris minor, Medicago denticulate*, *Cichorium intybus, Chenopodium album, Anagalis arvensis* and *Convolvulus arvensis.* Better activity of these herbicides against both broad leaved weeds could be assigned the reason for lower density and dry weight of the weeds. However, the hand weeding excelled to all the herbicidal treatments in reducing the population of weeds. These were due to complete elimination of weeds from the wheat field [40,41]. Halauxifen-methyl is considered to mimic to plant growth hormone auxin, resulting in the disruption of growth processes in susceptible plants. Cellular effects include alterations in cell wall elasticity and gene expression. Additionally, non- productive tissue growth is induced, resulting in epinasty and phloem disruption, preventing the movement of photosynthates and causing death in days to weeks [42].

The weed control efficiency of different treatments varied markedly due to weed control practices (Fig. 1). The weed control efficiency of halauxifen-methyl ester + florasulam at 7.6 g/ha, sulfosulfuron + metsulfuron methyl at 32.0 g/ha, metsulfuron + clodinafop at 10 g/ha and metsulfuron-methyl at 4 g/ha was poor (43.19, 46.77, 46.98 and 34.35%) as these herbicides didn't killed both grassy and broad leaved weeds. The application of metsulfuron alone given minimum weed control efficiency (34.35%) where as it was increased when the combined application of different herbicides. The combined application of halauxifen-methyl ester + florasulam at (10.20 g/ha) recorded maximum weed control efficiency (56.73%) followed by halauxifen-methyl ester + florasulam at 12.70 g/ha and halauxifen-methyl ester + florasulam at 25.50 g/ha. However, these herbicidal treatments did not surpass hand weeding, which had the maximum weed control efficiency (56.97) and proved superior over herbicidal treatments. It was due to complete eliminating all the weeds during critical period of crop weed competition in irrigated wheat (30-45 DAS) [43,44,45].

## 3.2 Effect on Crop

The effect of weed control treatments on growth parameters viz., plant height and number of tillers/$m^2$ was found significant at 60 DAS (Table 4). Weedy check plots had significantly minimum values of growth parameters from early growth period up to advanced growth stages due to severe crop-weed competition for growth resources leading to poor values of growth parameters. There was identical improvement in above parameters in plots receiving herbicidal treatments including hand weeding. Among the herbicidal treatments, application of halauxifen-methyl ester + florasulam at 10.20 g/ha recorded the higher plant height (66.47 cm) and number of tillers/$m^2$ (415.47). It was due to lesser crop-weed competition in this treatment led to proper root and shoot growth. These results attained the superior values of growth parameters. However, none of the herbicidal treatments surpass hand weeding as this treatment recorded the maximum values of plant height and number of tillers/$m^2$. These findings are in conforming to the findings of Dhiman [46]. Complete elimination of all weeds might have avoided the competetional stress and have prevailed congenial environment for better root and shoot growth. Henceforth, maximum values of these parameters were recorded under hand weeding [47].

Yield attributing trait i.e. grains per ear head was significantly influenced by different weed control treatments (Table 4). The values grains per ear head were minimum under weedy check plots due to poor growth parameters [48]. But there was appreciable improvement in this parameter in plots receiving herbicidal including mechanical weed control. Post emergence application of halauxifen-methyl ester + florasulam at 10.20 g/ha was found significantly superior and registered the higher value of grains per earhead (51.17) as compare to other remaining herbicidal treatments and at par to halauxifen-methyl ester + florasulam at 12.70 g/ha. However, none of the herbicidal treatments excelled to hand weeding which had the maximum value of grains per ear head [49]. The better growth and development of crop plants under aforesaid treatments on account of better control of weeds could be assigned the reason for better yield attributing trait under herbicidal treatments and complete weed free environment under hand weeding during critical period of crop-weed competition, led to record superior values of growth parameters, which in turn recorded the maximum values of yield attributing trait [50,51].

Grain yield of wheat varied significantly due to different weed control treatments (Table 4). The grain yield was recorded minimum under weedy plots (3.01 t/ha), where weeds were allowed to grow throughout the crop season. Due to which poor values of growth parameters and yield attributing traits were recorded. These situations results into lower grain yield. While maximum grain yield was recorded under hand weeding

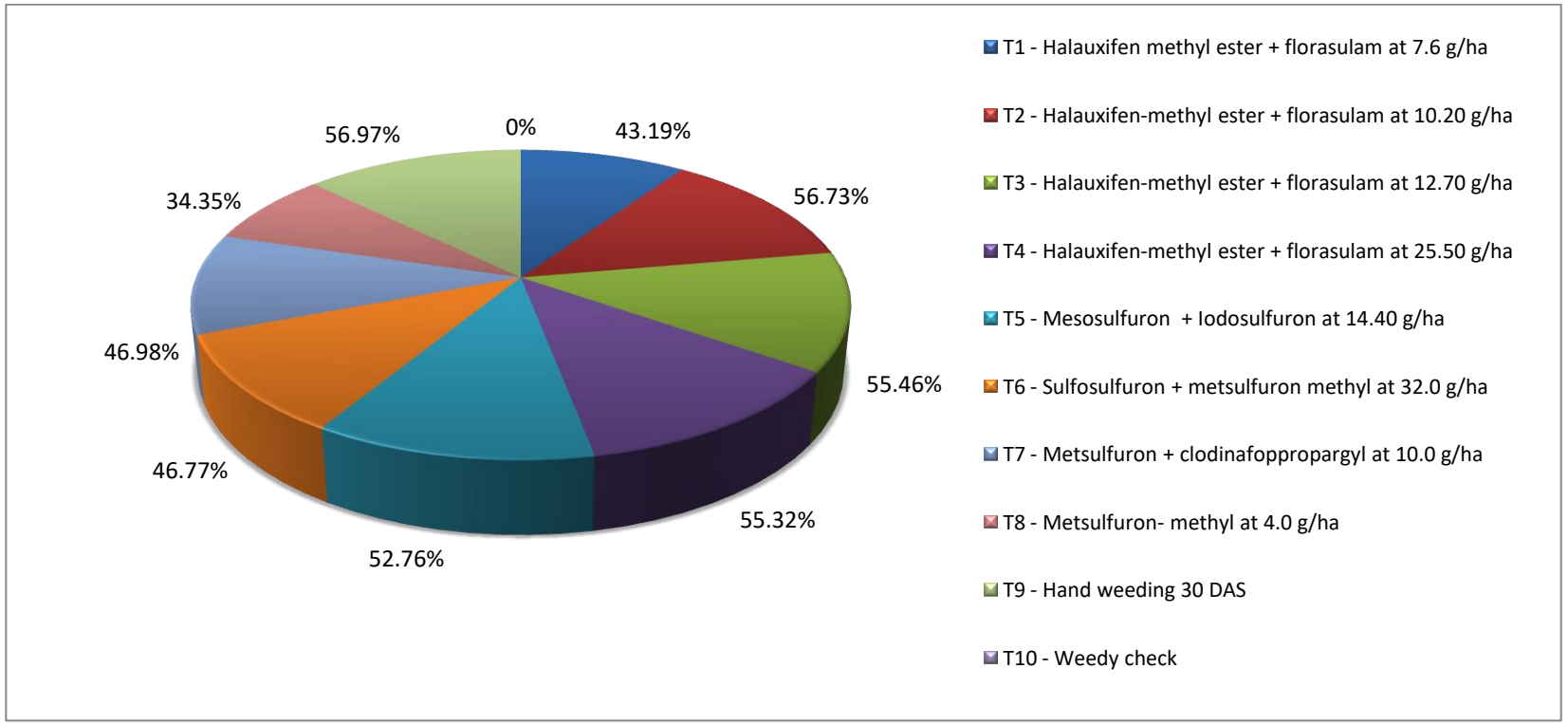


**Fig. 1. Influence of different herbicidal treatments on weed control efficiency (%) at 60 DAA in wheat**

**Table 2. Influence of different herbicidal treatments on weed density (no./m$^2$) at 60 DAA in wheat**

| Treatments | *Phalaris minor* | *Medicago denticulate* | *Cichorium intybus* | *Chenopodium album* | *Anagalis arvensis* | *Convolvulus arvensis* |
|---|---|---|---|---|---|---|
| $T_1$ - Halauxifen methyl ester + florasulam at 7.6 g/ha | 2.57 (6.13) | 2.16 (6.18) | 2.28 (4.70) | 2.14 (4.80) | 2.81 (7.42) | 2.71 (6.84) |
| $T_2$ - Halauxifen-methyl ester + florasulam at 10.20 g/ha | 2.18 (4.08) | 2.27 (4.44) | 2.22 (4.42) | 2.20 (4.34) | 2.64 (5.48) | 2.25 (4.58) |
| $T_3$ - Halauxifen-methyl ester + florasulam at 12.70 g/ha | 2.14 (4..10) | 2.26 (4.62) | 2.42 (5.35) | 2.16 (4.48) | 2.18 (5.57) | 2.24 (4.62) |
| $T_4$ - Halauxifen-methyl ester + florasulam at 25.50 g/ha | 2.13 (4.12) | 2.23 (4.78) | 2.50 (5.76) | 2.28 (4.72) | 2.51 (5.82) | 2.30 (4.78) |
| $T_5$ - Mesosulfuron + Iodosulfuron at 14.40 g/ha | 2.59 (6.22) | 2.91 (7.94) | 2.70 (6.81) | 2.22 (5.44) | 3.21 (9.79) | 2.73 (6.95) |
| $T_6$ - Sulfosulfuron + metsulfuron methyl at 32.0 g/ha | 2.59 (6.22) | 2.70 (6.80) | 3.19 (9.68) | 2.17 (5.22) | 2.73 (6.94) | 2.69 (6.72) |
| $T_7$ - Metsulfuron + clodinafoppropargyl at 10.0 g/ha | 2.69 (6.74) | 2.70 (6.80) | 2.99 (8.46) | 2.31 (5.84) | 2.73 (6.96) | 2.73 (6.94) |
| $T_8$ - Metsulfuron- methyl at 4.0 g/ha | 2.95 (8.23) | 1.95 (4.30) | 2.28 (4.72) | 2.25 (5.56) | 2.53 (5.88) | 2.75 (7.04) |
| $T_9$ - Hand weeding 30 DAS | 2.13 (4.04) | 2.66 (3.60) | 2.31 (4.14) | 1.98 (3.42) | 2.40 (4.26) | 2.20 (4.33) |
| $T_{10}$ - Weedy check | 3.13 (9.32) | 4.10 (16.34) | 3.11 (9.16) | 2.99 (8.46) | 3.12 (9.26) | 2.97 (8.34) |
| SEm± | 0.09 | 0.09 | 0.14 | 0.10 | 0.09 | 0.08 |
| CD at 5 % | 0.27 | 0.27 | 0.42 | 0.30 | 0.27 | 0.24 |

**Table 3. Influence of different herbicidal treatments on weed dry weight (g/m$^2$) at 60 DAA in wheat**

| Treatments | *Phalaris minor* | *Medicago denticulate* | *Cichorium intybus* | *Chenopodium album* | *Anagalis arvensis* | *Convolvulus arvensis* |
|---|---|---|---|---|---|---|
| $T_1$ - Halauxifen methyl ester + florasulam at 7.6 g/ha | 2.93 (8.09) | 1.91 (4.54) | 1.33 (1.47) | 1.67 (2.30) | 1.67 (2.30) | 1.89 (3.08) |
| $T_2$ - Halauxifen-methyl ester + florasulam at 10.20 g/ha | 2.47 (5.35) | 1.73 (5.48) | 1.30 (1.31) | 1.71 (2.43) | 1.58 (2.01) | 1.60 (2.06) |
| $T_3$ - Halauxifen-methyl ester + florasulam at 12.70 g/ha | 2.43 (5.39) | 1.99 (3.46) | 1.39 (1.44) | 1.69 (2.34) | 1.35 (1.32) | 1.59 (2.03) |
| $T_4$ - Halauxifen-methyl ester + florasulam at 25.50 g/ha | 2.42 (5.60) | 1.96 (4.48) | 1.44 (1.56) | 1.77 (2.64) | 1.52 (1.80) | 1.63 (2.15) |
| $T_5$ - Mesosulfuron + Iodosulfuron at 14.40 g/ha | 2.95 (8.21) | 2.54 (5.96) | 1.53 (1.84) | 1.73 (2.49) | 1.88 (3.03) | 1.91 (3.13) |
| $T_6$ - Sulfosulfuron + metsulfuron methyl at 32.0 g/ha | 2.95 (8.21) | 2.37 (5.10) | 1.76 (2.61) | 1.69 (2.36) | 1.63 (2.15) | 1.88 (3.02) |
| $T_7$ - Metsulfuron + clodinafoppropargyl at 10.0 g/ha | 3.07 (8.90) | 2.37 (5.10) | 1.67 (2.28) | 1.79 (2.71) | 1.63 (2.16) | 1.90 (3.12) |
| $T_8$ - Metsulfuron- methyl at 4.0 g/ha | 3.37 (10.86) | 1.99 (4.36) | 1.33 (1.80) | 1.75 (2.55) | 1.52 (1.82) | 1.92 (3.17) |
| $T_9$ - Hand weeding 30 DAS | 2.41 (4.33) | 2.33 (3.95) | 1.35 (1.19) | 1.56 (1.92) | 1.46 (1.63) | 1.57 (1.95) |
| $T_{10}$ - Weedy check | 3.58 (12.30) | 3.57 (12.26) | 1.72 (2.47) | 2.29 (4.74) | 1.84 (2.87) | 2.06 (3.75) |
| SEm± | 0.09 | 0.08 | 0.09 | 0.08 | 0.09 | 0.07 |
| CD at 5 % | 0.26 | 0.23 | 0.27 | 0.24 | 0.28 | 0.20 |

**Table 4. Influence of different herbicidal treatments on growth parameters, yield attributes and grain yield in wheat**

| Treatments | Plant height (cm) 60 DAS | Number of tillers/$m^2$ 60 DAS | Grains /ear head | Grain yield (t/ha) | Harvest index (%) |
|---|---|---|---|---|---|
| $T_1$ - Halauxifen methyl ester + florasulam at 7.6 g/ha | 66.07 | 380.27 | 42.00 | 5.28 | 44.78 |
| $T_2$ - Halauxifen-methyl ester + florasulam at 10.20 g/ha | 66.47 | 415.47 | 51.17 | 5.81 | 44.99 |
| $T_3$ - Halauxifen-methyl ester + florasulam at 12.70 g/ha | 66.00 | 354.13 | 49.25 | 5.74 | 44.69 |
| $T_4$ - Halauxifen-methyl ester + florasulam at 25.50 g/ha | 65.67 | 386.13 | 47.74 | 5.69 | 44.00 |
| $T_5$ - Mesosulfuron + Iodosulfuron at 14.40 g/ha | 65.87 | 394.00 | 42.00 | 4.81 | 42.76 |
| $T_6$ - Sulfosulfuron + metsulfuron methyl at 32.0 g/ha | 65.53 | 402.53 | 46.20 | 5.33 | 43.80 |
| $T_7$ - Metsulfuron + clodinafoppropargyl at 10.0 g/ha | 65.27 | 382.93 | 45.56 | 5.07 | 43.33 |
| $T_8$ - Metsulfuron- methyl at 4.0 g/ha | 63.33 | 395.87 | 44.75 | 4.86 | 43.18 |
| $T_9$ - Hand weeding 30 DAS | 67.13 | 429.07 | 52.27 | 5.90 | 45.00 |
| $T_{10}$ - Weedy check | 55.73 | 355.87 | 38.25 | 3.01 | 40.13 |
| SEm± | 1.65 | 0.04 | 0.02 | 0.03 | - |
| CD at 5 % | 4.78 | 0.13 | 0.06 | 0.09 | - |

treatment and it surpassed all the herbicidal treatments in terms of grain yields due to the superior values of yield attributing traits [52]. Among the herbicidal treatments, post emergence application of halauxifen-methyl ester + florasulam at 10.20 g/ha caused significant impressment in grain yield and recorded the higher grain yield (5.81 t/ha) *fb* halauxifen-methyl ester + florasulam at 12.70 g/ha. It was due to effective weed control with the herbicidal application which provide weed free environment to crop plant for the growth and development [53,54]. Weed control brought down competition and created congenial micro-environment for better establishment and growth of wheat crop. The herbicide sequence comprising halauxifen + florasulam increased grain yield and its better weed control provided all favourable conditions like increased availability of nutrients, moisture, light and other factors to the crop which in turn resulted in higher dry matter production [55].

Harvest index of different weed control treatments was calculated and given in Table 4. The Post emergence application of all the herbicidal treatment recorded higher harvest index over weedy check plots. The higher value of harvest index was recorded in the treatment halauxifen-methyl ester + florasulam at 10.20 g/ha (44.99%) *fb* halauxifen-methyl ester + florasulam at 7.6 g/ha *fb* halauxifen-methyl ester + florasulam at 12.70 g/ha. However, maximum harvest index was recorded under hand weeding treatment among all the weed control treatments [56].

## 4. CONCLUSION

It can be concluded that, the density and diversity of weeds was significantly altered by different weed management practices and these practices successfully reduced the density of dominated weeds. Highest magnitude of suppression was recorded with the post emergence application of halauxifen-methyl ester + florasulam at 10.20 g/ha and it was the best combination for effective control of grasses and broad leaved weeds which leads to maximum grain yield in wheat crop.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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