Original Research Article

Efficacy of halauxifen-methyl + florasulam against complex weeds in wheat under Kymore plateau and Satpura hill zone of Madhya Pradesh

ABSTRACT

Wheat crop is inhabited by several monocot and dicot weeds which have posed a major problem in wheat crop production. These weeds not only reduce the quality and quantity of the produce but also increase the cost of production. There management therefore becomes crucial with the help of proper combination of herbicides considering the bottlenecks of mechanical methods. Thus, a field experiment was conducted in the *rabi* season of 2016-2017 at the research farm of Department of Agronomy, JNKVV, Jabalpur. The experiment was laid out in randomized block design with ten treatments including eight herbicidal combinations with hand weeding at 30 DAS and weedy check and replicated thrice. Various observation on weed and crop growth parameters, yield, and economics were made. The results indicated that the application of halauxifen-methyl + florasulam at 10.20 g/ha significantly reduced the weed density and dry weight, increased the plant height, number of tillers and leaf area index as compared to all other herbicidal treatments with an exception to hand weeding. It also enhanced the grain and straw yield (5810.12 kg/ha and 7103.75 kg/ha). The application of halauxifen-methyl + florasulam at 10.20 g/ha recorded highest net monetary returns (104555 Rs/ha) and resulted in maximum benefit with a B:C ratio of 3.8. Thus, this could be promising technology for controlling weeds in wheat crop.

Keywords: B:C ratio, Florasulam, Halauxifen-methyl, Net monetary returns, Weeds

1. INTRODUCTION

Wheat (*Triticum aestivum* L.), a significant grain crop in India, is a staple diet for billions of people worldwide [1, 2]. India produces 13.5% of the world's wheat, which is second only to China in terms of output [3]. It is India's second-most significant foodgrain crop after rice, meeting almost 50% of the country's population's overall protein and calorie needs [4]. According to [5], there are about 31.45

million hectares (m ha) of wheat cultivated in India, with a production of 107.59 million tonnes (mt) and an average productivity of 3.53 t/ha. On over 10.02 million hectares in Madhya Pradesh, wheat is grown, yielding 16.52 million tonnes of grain with a productivity of 3298 kg/ha [6]. According to [7, 8], wheat is produced over a significant part of India, from latitudes of 60° N to 60° S, and at elevations varying from sea level to as high as 3500 m in the tropics and subtropics.

Weeds are among the agricultural pest that can be influenced by various factors including climate change [9, 10]. Weeds are one of the main obstacles to wheat production since they raise harvest costs, diminish yield owing to competition and allelopathy, provide homes for diseases, and serve as alternate hosts for a variety of insects and fungus [11]. In comparison to the combined effects of insect pests and diseases, weed competition causes larger agricultural losses across the world. It reduces wheat production by 10–65% [12, 13]. The management of weed thus becomes crucial [14, 15]. Physical techniques are challenging due to the labour costs, draught animals, and other costs involved, it is now required to utilize chemical weed management since crop mimicry makes managing weeds ineffective and costly [16, 17].

In contrast to manual or mechanical weeding, which may not be feasible given their high cultivation costs [18, 19], chemical weed management through the use of post-emergence herbicides can result in the efficient and affordable control of weeds during the key period of crop weed competition [20]. To get advantageous returns, the most suitable herbicide must be chosen, along with the right application timing and dose [21, 22]. Herbicide use results in a considerable reduction in the dry weight of weeds as compared to non-treated plots, as well as an increase in yield components and grain yield [23, 24]. Therefore, the exploration and evaluation of newer combination of herbicides is excellent option for efficient weed control. In view of these facts the present study was designed to evaluate the efficacy of halauxifen-methyl + florasulam on weeds, growth, and yield of wheat.

2. MATERIALS AND METHODS

A field experiment was conducted during *rabi* 2016-2017 at the research farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (23°9' North and 79°58' East with an altitude of 411.78 m above mean sea level). The soil was clayey in texture, neutral in reaction (*p*H 7.3) with electrical conductivity of 0.32 dS/m, medium in organic carbon (0.64%), available N (370.0 kg/ha), available P (16.0 kg /ha) and high in available K (298 kg/ha). The experiment was laid out in randomized block design with three replications. There were ten treatments in the experiment which consisted of post emergence application of eight herbicidal combinations viz., 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}). Wheat cultivar GW-273 was sown on December 1, 2016 at a row spacing of 22 cm by drilling at the seed rate of 100 kg/ha. The crop was fertilized with 120:60:40 kg of N: P_2O_5: K_2O per hectare through urea, single super phosphate and muriate of potash, respectively. All the herbicides were applied at 20 DAS with the help of a knapsack sprayer with a flat fan nozzle using a spray volume of 500 l/ha. Various observations pertaining to weeds and crop were made during the crop growing season. Dominant weed flora and their species wise density were recorded under all the treatments at 30 DAS. To normalize the distribution of the data on weed count and dry weight, square root transformation (X+1) was applied [25]. Plant population was recorded at 30 DAS. Growth parameters viz. plant height, tillers/m^2, leaf area index were recorded at 30 DAS. Test weight, grain yield, straw yield and weed index was recorded. Harvesting was done when the panicle matured and plant was dried up. The threshing of the crop was done by manually by plot wise and grain and straw were conducted separately. The grain yield was recorded as kg/plot and then converted into kg/ha. The entire cost of cultivation was subtracted from the gross returns to determine the net returns, and the benefit:cost ratio was derived by dividing the net returns by the total cost of cultivation. The data was analyzed statistically by using the techniques of the analysis of variance (ANOVA) and the treatment was tested by F test shown. Critical difference (CD) at 5% level of significance was determined for each character to compare the differences among treatment means.

3. RESULTS AND DISCUSSION

3.1. Weed flora

The weed flora of the experimental field was mainly dominated by monocot and dicot weeds. Among monocots, the relative density of *Phalaris minor* (15.33%) and among dicots, *Medicago denticulate* (27.14 %), *Cichorium intybus* (15.63 %) were found most dominant. However, other weeds like *Anagallis arvensis, Convolvulus arvensis* and *Chenopodium album* were also found to be associated in a lesser number (Figure 1). Thus, there is a predominance of mixed weed flora in wheat. These findings were in confirmation with [26, 27, 28].

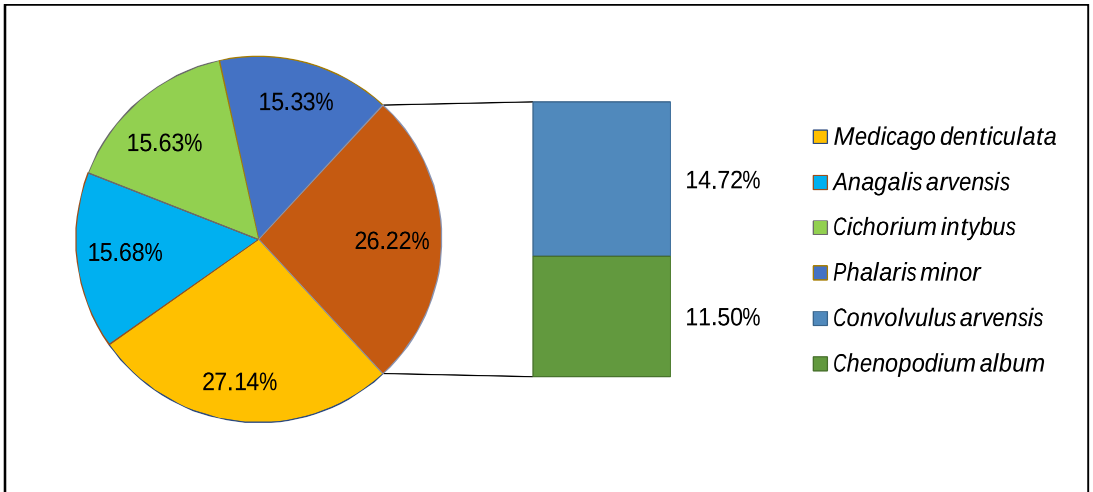

Figure 1. Relative density of weeds in wheat crop

3.2. Weed density and dry weight

Different weed control treatments had a significant influence on the density and dry weight of different weeds at 30 DAS (Table 1 and 2). The density and dry weight of different weeds were found to be highest in weedy check plots which might be due to higher growth of weeds in since no weed control treatments were applied. The hand weeding had obtained highest control of weeds which resulted in lowest weed density and dry weight at 30 DAS. All the herbicides reduced the weed density and dry weight at 30 DAS as compared with untreated weedy check. The post emergence application of halauxifen-methyl ester + florasulam (T_2) at 10.20 g/ha resulted in lower density and dry weight of different weeds. This could be attributed to application of herbicide within critical period of weed competition which inhibited the protein synthesis resulted in better weed control [29, 30, 31].

Table 1. Influence of different herbicidal treatments on weed density (no./m^2) at 30 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	2.60 (6.24)□	4.02 (15.68)	2.35 (5.04)	2.17 (4.62)	2.95 (8.22)	3.29 (10.32)
T_2 - Halauxifen-methyl ester + florasulam at 10.20 g/ha	2.19 (4.08)	2.84 (4.56)	2.26 (4.60)	2.22 (4.44)	3.49 (6.66)	2.95 (8.32)
T_3 - Halauxifen-methyl ester + florasulam at 12.70 g/ha	2.16 (4.16)	2.37 (5.10)	2.46 (5.54)	2.21 (4.48)	4.12 (7.44)	2.99 (8.46)
T_4 - Halauxifen-methyl ester + florasulam at 25.50 g/ha	2.14 (4.18)	2.26 (5.62)	3.31 (10.44)	2.34 (4.96)	2.84 (8.56)	3.06 (8.88)

T_5 - Mesosulfuron + iodosulfuron at 14.40 g/ha	2.60 (6.28)	3.26 (10.12)	2.97 (8.32)	2.27 (4.66)	4.01 (15.56)	3.32 (10.50)
T_6 - Sulfosulfuron + metsulfuron methyl at 32.0 g/ha	2.71 (6.84)	3.31 (10.44)	3.21 (9.78)	2.41 (5.32)	2.84 (7.54)	3.36 (10.82)
T_7 - Metsulfuron + clodinafoppropargy l at 10.0 g/ha	2.71 (6.82)	3.27 (10.22)	3.20 (9.76)	2.41 (5.32)	2.84 (7.56)	3.33 (10.59)
T_8 - Metsulfuron-methyl at 4.0 g/ha	2.99 (8.46)	2.24 (6.52)	3.01 (8.57)	2.30 (4.78)	2.62 (6.34)	3.35 (10.72)
T_9 - Hand weeding 30 DAS	2.18 (4.05)	3.34 (6.05)	3.13 (3.32)	2.04 (3.67)	2.84 (7.56)	2.96 (8.26)
T_{10} - Weedy check	3.29 (10.34)	4.56 (20.32)	3.43 (11.27)	3.03 (8.69)	3.47 (11.56)	3.44 (11.34)
SEm±	0.10	0.08	0.12	0.11	0.09	0.10
CD at 5 %	0.29	0.24	0.37	0.34	0.27	0.30

**Values under parenthesis (□) are the original values

Table 2. Influence of different herbicidal treatments on weed dry weight at 30 DAA in wheat

Treatments	*Phalaris minor*	*Medicago denticulat e*	*Cichoriu m intybus*	*Chenopo dium album*	*Anagalis arvensis*	*Convolvulu s arvensis*
T_1 - Halauxifen methyl ester + florasulam at 7.6 g/ha	2.78 (7.24)□	2.57 (6.12)	1.31 (2.21)	1.48 (1.69)	1.70 (2.38)	1.73 (2.48)
T_2 - Halauxifen-methyl ester + florasulam at 10.20 g/ha	2.34 (4.96)	1.50 (4.16)	1.26 (1.33)	1.51 (1.78)	1.97 (3.38)	1.57 (1.97)
T_3 - Halauxifen-methyl ester + florasulam at 12.70 g/ha	2.31 (4.98)	1.58 (1.99)	1.35 (2.24)	1.50 (1.75)	2.30 (4.77)	1.59 (2.03)
T_4 - Halauxifen-methyl ester + florasulam at 25.50 g/ha	2.29 (5.05)	1.52 (1.08)	1.73 (2.51)	1.57 (1.98)	1.64 (2.19)	1.62 (2.13)
T_5 - Mesosulfuron + iodosulfuron at 14.40 g/ha	2.79 (7.28)	2.11 (3.95)	1.58 (2.67)	1.54 (1.86)	2.24 (4.51)	1.74 (2.52)
T_6 - Sulfosulfuron + metsulfuron methyl at 32.0 g/ha	2.90 (7.93)	2.14 (4.07)	1.69 (2.78)	1.62 (2.13)	1.64 (2.19)	1.76 (2.60)
T_7 - Metsulfuron + clodinafoppropargyl at 10.0 g/ha	2.90 (9.91)	2.12 (3.99)	1.69 (2.82)	1.62 (2.13)	1.64 (2.19)	1.74 (2.54)
T_8 - Metsulfuron-methyl at 4.0 g/ha	3.21 (9.81)	1.86 (1.95)	1.60 (3.06)	1.55 (1.91)	1.53 (1.84)	1.75 (2.57)
T_9 - Hand weeding 30 DAS	2.33 (4.93)	2.16 (1.76)	1.66 (1.10)	1.40 (1.47)	1.64 (2.19)	1.57 (1.98)
T_{10} - Weedy check	3.53	2.90	1.79	1.99	1.96	1.79

	(11.99)	(7.92)	(2.70)	(3.480)	(3.35)	(2.72)
SEm±	0.07	0.06	0.08	0.06	0.06	0.06
CD at 5 %	0.20	0.19	0.24	0.18	0.18	0.13

**Values under parenthesis (□) are the original values

3.3. Crop growth parameters

The crop growth during the entire growth period has a direct impact on the yield of the crop. In the experimental findings, it was reported that all the crop growth parameters such as plant height, number of tillers per square meters and leaf area index were significantly affected by the weed control treatments except plant population (Table 3).

The plant population was not significantly impacted by the weed control treatments. it was evident that the weed control treatments had similar population as compared to hand weeded and weedy check plots at 30 DAS and at harvest. This also indicated that that herbicidal treatments did not cause any phytotoxicity to crop plants after their application as post emergence.

All the herbicidal treatments recorded higher growth parameters of wheat over control treatment at 30 DAS **(**Table 3). Among the weed control treatments, weedy check plot exhibited lowest plant height, no. of tillers per m^2 and leaf area index which might be due to the severe competition for the growth resources posed by the weeds. on the contrary, hand weeding treatment recorded highest values of all the growth parameters. Among the herbicidal treatments, the post emergence application of halauxifen-methyl ester + florasulam at 10.20 g/ha (T_2) recorded highest plant height (26.73 cm), no. of tillers per m^2 (269.87) and leaf area index (2.81). This might be due to the effective control of weeds which facilitated the profuse growth of the crop. Similar findings are also reported by [32, 33, 34].

Table 3. Influence of different herbicidal treatments on growth parameters at 30 DAS in wheat

Treatments	**Plant Population/m^2**	**Plant height (cm)**	**No. of tillers/m^2**	**Leaf area Index**
T_1 - Halauxifen methyl ester + florasulam at 7.6 g/ha	259.0	25.20	263.20	2.73
T_2 - Halauxifen-methyl ester + florasulam at 10.20 g/ha	258.0	26.73	269.87	2.81
T_3 - Halauxifen-methyl ester + florasulam at 12.70 g/ha	250.2	25.27	254.53	2.80
T_4 - Halauxifen-methyl ester + florasulam at 25.50 g/ha	257.5	25.80	254.53	2.78
T_5 - Mesosulfuron + iodosulfuron at 14.40 g/ha	249.6	25.67	265.60	2.58
T_6 - Sulfosulfuron + metsulfuron methyl at 32.0 g/ha	249.2	24.73	254.67	2.75
T_7 - Metsulfuron + clodinafoppropargyl at 10.0 g/ha	257.1	25.40	253.73	2.71
T_8 - Metsulfuron- methyl at 4.0 g/ha	255.5	24.73	255.47	2.65

T_9 - Hand weeding 30 DAS	257.8	25.87	270.13	2.83
T_{10} - Weedy check	251.1	20.67	246.13	2.36
SEm±	1.51	0.75	0.30	0.02
CD at 5 %	NS	2.17	0.89	0.08

3.4 Yield attributes and yields of the crop

The information about test weight, grain yield, straw yield and weed index varied significantly amongst the weed-management techniques (Table 4). All weed control treatments produced significantly higher test weight, grain, and straw yields of wheat than weedy check. Higher test weight, grain, and straw yields were recorded under hand weeding at 30 DAS. On the contrast, the weedy check produced lowest test weight of seeds, grain yield and straw yield which may be due to the limited growth resources available to the crop owing to higher weed competition. Among the herbicidal treatments, the application of halauxifen-methyl ester + florasulam at 10.20 g/ha (T_2) recorded highest test weight (36.8 g), grain yield (5810.12 kg/ha) and straw yield (7103.75 kg/ha). The increase in the growth parameters of the crop due to better control of weeds might have resulted in the higher yield attributes and yield of the crop [35, 36, 37].

Weed index is a measure of the reduction in crop yield due to the presence of weed in comparison to weed-free plots. The careful perusal of the data (Table 4) indicated that the maximum yield loss of 50.25% was recorded under weedy check due to the uncontrolled growth of weeds during the entire crop growth season. But it was decreased appreciably in plots receiving herbicidal weed control being the zero under hand weeded plots. Among the herbicidal treatments, the weed index was lowest (4.05 %) in plots receiving the application of halauxifen-methyl ester + florasulam at 10.20 g/ha (T_2). Weeds made circumstances for nutrients, space, soil moisture, and light challenging; as a result, wheat crops growth and development were inhibited. In addition to reducing weed density, the herbicide spray also reduced weed dry matter and decreased crop-weed competition. The findings are in close conformity with the earlier findings of [38].

Table 4. Influence of different herbicidal treatments on weed dry weight at 30 DAA in wheat

Treatments	**Test weight (g)**	**Grain yield (kg/ha)**	**Straw yield (kg/ha)**	**Weed index (%)**
T_1 - Halauxifen methyl ester + florasulam at 7.6 g/ha	36.3	5289.75	6474.03	22.55
T_2 - Halauxifen-methyl ester + florasulam at 10.20 g/ha	36.8	5810.12	7103.75	4.05
T_3 - Halauxifen-methyl ester + florasulam at 12.70 g/ha	36.2	5744.35	7110.10	6.79
T_4 - Halauxifen-methyl ester + florasulam at 25.50 g/ha	36.0	5694.66	7248.67	7.61
T_5 - Mesosulfuron + iodosulfuron at 14.40 g/ha	35.4	4812.41	6442.62	20.53

T_6 - Sulfosulfuron + metsulfuron methyl at 32.0 g/ha	35.8	5334.05	6845.23	11.91
T_7 - Metsulfuron + clodinafoppropargyl at 10.0 g/ha	35.7	5078.35	6642.23	16.14
T_8 - Metsulfuron- methyl at 4.0 g/ha	35.6	4860.75	6396.53	19.73
T_9 - Hand weeding 30 DAS	36.9	5905.90	7317.92	0.00
T_{10} - Weedy check	35.2	3012.35	4493.50	50.25
SEm±	0.76	30.00	35.50	-
CD at 5 %	2.22	90.00	105.50	-

3.5 Economics

The weed control treatments strongly impacted economics of the system (Table 5). Economic analysis revealed that the highest gross monetary returns (141766 Rs/ha), net monetary returns (104555 Rs/ha) and benefit:cost ratio (3.8) were received with the post emergence application of halauxifen-methyl ester + florasulam at 10.20 g/ha (T_2). The lowest GMR, NMR and B:C ratio however, were produced by unweeded checks. Similar findings are also reported by [38].

Table 5. Influence of different herbicidal treatments on economics in wheat

Treatments	**Gross monetary return (Rs/ha)**	**Net monetary return (Rs/ha)**	**B :C ratio**
T_1 - Halauxifen methyl ester + florasulam at 7.6 g/ha	128454	91267	3.5
T_2 - Halauxifen-methyl ester + florasulam at 10.20 g/ha	141766	104555	3.8
T_3 - Halauxifen-methyl ester + florasulam at 12.70 g/ha	140122	102888	3.8
T_4 - Halauxifen-methyl ester + florasulam at 25.50 g/ha	139264	101912	3.7
T_5 - Mesosulfuron + iodosulfuron at 14.40 g/ha	120617	81926	3.1
T_6 - Sulfosulfuron + metsulfuron methyl at 32.0 g/ha	130097	92855	3.5
T_7 - Metsulfuron + clodinafoppropargyl at 10.0 g/ha	124983	87641	3.3
T_8 - Metsulfuron- methyl at 4.0 g/ha	120303	83164	3.2
T_9 - Hand weeding 30 DAS	143731	101014	3.4
T_{10} - Weedy check	75974	39257	2.1

4. CONCLUSION

Weeds are always a menace in the wheat crop production. Their control therefore, becomes necessary with the help of a proper combination of herbicides. Henceforth, based on the experimental study it can be concluded that the application of halauxifen-methyl ester + florasulam at 10.20 g/ha reduced the weed density and dry weight, increased the growth, and resulted in higher grain and straw yield and higher returns. Thus, this technology can be recommended to the farmers for the control of diverse weed species in wheat.

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