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EFFICACY OF HERBICIDES FOR BROADLEAF WEEDS MANAGEMENT IN WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract

The field experiment was conducted at the Punjab Agricultural University, Ludhiana, Punjab during 2016-17 and 2017-18. The experiment was comprised of eleven treatments with three replications. The treatments were halauxifen-methyl ester + florasulam 40.85% WG + polyglycol 26-2 N (12.76 g/ha), metsulfuron methyl 20 WG + surfactant (4g/ha), carfentrazone 40DF (20 g/ha), 2,4-D (Na salt) 80 WP (500 g/ha), 2,4-D (ethyl ester) 38 EC (500 g/ha), metsulfuron + carfentrazone + surfactant (4 + 20 g/ha), 2,4-D Na + carfentrazone (400 + 20 g/ha), 2,4-D (ethyl ester) + carfentrazone (400 + 20 g/ha), halauxifen-methyl ester + florasulam + carfentrazone + surfactant (10.21 + 20 g/ha), weedy check and weed free. Metsulfuron + carfentrazone + surfactant recorded the lowest weed density. Halauxifen-methyl ester + florasulam + polyglycol, halauxifen-methyl ester + florasulam + carfentrazone + surfactant, carfentrazone and all combinations of carfentrazone recorded similar weed dry matter recorded at harvest and weed index. The grain yield and B:C ratio recorded in halauxifen-methyl ester + florasulam + ply, halauxifen-methyl ester + florasulam + carfentrazone + surfactant, carfentrazone and all combinations of carfentrazone was similar to weed free treatment. So, the new herbicide halauxifen-methyl ester + florasulam + poly can be used to control broafleaf weeds especially in the field which are infested with *Malva neglecta*.

Key words: Carfentrazone, economics, halauxifen + florasulam, weed control efficiency, wheat.

Introduction

Wheat (*Triticum aestivum* L.) is the major *rabi* cereal crop grown in India. It was grown on an area of 31.0 m hectares with total production of 101.2 m tonnes during 2018-19 (Anonymous, 2019). Weeds, insects' pest and diseases caused considerable loss to the wheat productivity though competing with water, nutrients, space and sun light. Among the weeds grass and broadleaf weeds are the major weeds which are causing considerable loss to wheat yield, quality and increasing the cost of processing (Zimdahl, 2013). Gharde *et al.,* (2018) reported actual economic losses due to weeds in India in wheat (US$ 3376 million) is next to rice (US$ 4420 million) followed by soybean (US$ 1559 million).

Although herbicides are being used to control weed since long time back but herbicide resistance is the serious issue in weed management. Many researchers advise applications of herbicides with different mode of action in rotation to avoid/delay herbicide resistance. Some of the broadleaf weeds like button weed (*Malva neglecta*) are not being controlled under north Indian conditions with 2,4-D and metsulfuron. Herbicides are major tool to control weed menace in most wheat growing areas of the region. The complexity and diversity of weed flora may require more than one herbicide either in sequence or as tank mixture (Khokan and Chavak, 2011). Singh *et al.,* (2015) reported that post emergence application of metsulfuron-methyl 20% WG@ 4 g ha^{-1} + 0.2% surfactant reduced broadleaf weed population and total weed dry weight significantly. Singh *et al.,* (2011) reported that premix of carfentrazone + metsulfuron at 25 g/ha + 0.2% surfactant provided effective control of *Malva parviflora, Lathyrus aphaca, Convolvulus arvensis, Rumex dentatus, Melilotus indica, Medicago denticulata, Anagallis arvensis, Coronopus didymus* and *Chenopodium album* which were not effectively controlled by alone application of these herbicides. They further reported that a non-ionic surfactant was essential to increase the efficacy of pre-mix carfentrazone + metsulfuron. Carfentrazone-ethyl, a post-emergence contact herbicide which kills weeds by desiccation of leaves, has no soil residual activity and is compatible with many herbicides for effective control of several weeds when applied at early growth stage of weeds (Varshney

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et al., 2012). Broadleaf weeds viz., *Malva parviflora* and *Convolvulus arvensis* are not effectively controlled by 2,4-D or metsulfuron, but carfentrazone is very effective against these weed species (Punia *et al.,* 2006). Halauxifen methyl is a novel arylpicolinate herbicide with an auxinic mode of action whereas florasulam acts through inhibition of the plant enzyme acetolactate synthase (ALS). It is taken up by plant root and shoots and translocated in both xylem and phloem (Tomlin, 2006). These herbicides will provide a new option for the control of broadleaf weeds including those with resistance to other herbicides. Halauxifen-methyl ester + florasulam 40.85% WG novel synthetic auxin herbicide was found to be effective for controlling the broadleaf weeds in wheat (Mitra *et al.,* 2019). The issue of poor broadleaf weed control with few herbicides is attributed to introduce new herbicides to control these in wheat crop. The objective of the present studies was to determine if halauxifen plus florasulam alongwith surfactants and metsulfuron plus carfentrazone ethyl and tank mix of carfentrazone and 2,4-D (Na salt and ethyl ester) could provide better control of weeds and higher wheat yield than individual application of 2,4-D, metsulfuron and carfentrazone as presently applied broadleaf herbicides.

Materials and Methods

The experiment was conducted at the research farm of the Punjab Agricultural University, Ludhiana, Punjab. The soil of the experimental field was loamy sand in texture and has low N (178.5 kg/ha), high P (33.8 kg/ha) and medium K (179.2 kg/ha) content and 7.8 soil pH. The experiment was conducted in randomized complete block design with eleven treatments and three replications. The experiment was comprised of eleven treatments with three replications. The treatments were halauxifen-methyl ester + florasulam 40.85% WG + polyglycol 26-2 N (12.76 g/ha), metsulfuron methyl 20 WG + surfactant (4g/ha), carfentrazone 40DF (20 g/ha), 2,4-D (Na salt) 80 WP (500 g/ha), 2,4-D (ethyl ester) 38 EC (500 g/ha), metsulfuron + carfentrazone + surfactant (4+20 g/ha), 2,4-D Na + carfentrazone (400+20 g/ha), 2,4-D (ethyl ester) + carfentrazone (400+20 g/ha), halauxifen-methyl ester + florasulam + carfentrazone + surfactant (10.21+20 g/ha), weedy check and weed free. Wheat variety PBW 725 was sown on November 03 and 6, respectively, during 2016 and 2017 at a row spacing of 20 cm using 100 kg seed rate/ha. The recommended dose of fertilizer (150 kg nitrogen and 27.3 kg phosphorus) was applied. Half nitrogen dose and whole phosphorus was applied at the time of sowing. The second dose of nitrogen was applied at first irrigations. The field was infested with natural weed flora dominated by buttonweed (*Malva neglecta* L.). Herbicides were sprayed on December 7 in both years with a backpack sprayer fitted with flat fan which was delivering 375 L. water volume/ha. Grass weeds (*Phalaris minor* and *Avena ludoviciana*) were controlled by spraying of clodinafop @ 60 g/ha on December 12 in both the years. The crop was raised with recommended cultural practices of the Punjab Agricultural University, Ludhiana. The weed population and weed dry weight was recorded using a quadrant of 0.5 × 0.5 m at 60 days after sowing and at harvest. The weed control efficiency, herbicide efficiency index and weed index were calculated with given equations:

$$\text{Weed control efficiency} = \frac{\text{Weed dry matter in weedy check - Weed dry matter in treated plot}}{\text{Weed dry matter in weedy check plot}}$$

$$\text{Herbicide efficiency index} = \frac{\dfrac{\text{Grain yield of treatment - Grain yield of weedy check}}{\text{Grain yield of weedy check}} \times 100}{\dfrac{\text{Weed dry matter in treatment}}{\text{Weed dry matter in weedy check}} \times 100}$$

$$\text{Weed index} = \frac{\text{Grain yield of weed free - Grain yield of treatment}}{\text{Grain yield of weed free}}$$

The emergence count was recorded 14 days after sowing and presented as emergence count per metre square. The plant height, effective tillers, thousand grain weight, number of grains per earhead, biological and grain yield of wheat was recorded at harvest from net plot of 9.8 square metre. The data from two years were pooled to ANOVA using OP Stat for statistical analysis.

Results and Discussion

Weed flora, weed density and weed dry matter

The major weed in the field was *Malva neglecta* (96%) although other weeds like *Chenopodium album* and *Anagalis arvesnsis* were also present but their population was less than 5% (Table 1). The weed density before herbicide application was uniform as the results were non-significant. The weed density recorded at 60 days after sowing (DAS) in weedy check was the highest which was significantly higher than all the herbicide treatments. Any of the treatment was not statistically at par weed free treatment. However, among the herbicide treatments, the lowest weed density at 60 DAS and at harvest was recorded in metsulfuron + carfentrazone + surfactant which was statistically at par with 2,4-D (Na salt/Ethlyl estrer) + carfentrazone. Weed density in best herbicide treatment of metsulfuron + carfentrazone + surfactant recorded 91.2% less as compared to the weedy check. Chhokar *et al.,* (2015) reported that pre-mix formulation of matsulfuron + carfentrazone + surfactant was more effective in controlling *Lathyrus aphaca* (meadow peavine), *Malva parviflora* (little mallow) and *Solanum nigrum* (black nightshade).

The weed dry matter recorded at 60 DAS was the lowest in weed free treatment. No herbicide treatment was able to reduce the weed dry matter statistically at

Table 1: Effect of weed control treatments on weeds density and weeds dry matter accumulation.

Treatment	Dose (g a.i./ha)	Weeds density (no./ m²)						Weed dry matter (g/m²)			
		Before treatment		60 DAS		At harvest		60 DAS		At harvest	
		O	T	O	T	O	T	O	T	O	T
T_1 Halauxifen + florasulam + Poly	12.75	34.7	(6.0)	8.9	(3.0)	11.8	(3.5)	59.3	(6.8)	73.8	(7.5)
T_2 Metsulfuron + surfactant (S)	4	38.0	(6.2)	23.4	(4.8)	26.4	(5.1)	97.7	(8.3)	148.3	(8.5)
T_3 Carfentrazone	20	37.3	(6.2)	5.8	(2.5)	8.3	(3.0)	41.4	(5.7)	59.0	(6.4)
T_4 2,4-D Na (Na salt)	500	31.6	(5.7)	24.8	(5.0)	29.9	(5.5)	98.9	(8.4)	155.3	(9.7)
T_5 2,4-D EE (Ethyl ester)	500	40.6	(6.4)	22.5	(4.7)	23.1	(4.7)	102.0	(8.4)	147.7	(9.8)
T_6 Metsulfuron + carfentrazone +S	4+20	37.0	(6.2)	3.2	(2.0)	5.0	(2.4)	37.8	(5.1)	42.3	(5.4)
T_7 2,4-D Na + carfentrazone	400+20	34.3	(5.9)	4.8	(2.4)	6.9	(2.8)	39.3	(5.4)	69.5	(6.8)
T_8 2,4-D EE + carfentrazone	400+20	40.3	(6.4)	3.9	(2.2)	6.3	(2.7)	33.9	(4.9)	48.3	(5.6)
T_9 Halauxifen + florasulam+	10.21+20	35.3	(6.0)	8.4	(2.9)	11.9	(3.5)	50.2	(6.4)	144.7	(9.0)
T_{10} Weedy check carfentrazone + S	-	34.2	(5.9)	36.2	(6.1)	39.6	(6.3)	118.9	(9.5)	278.2	(13.5)
T_{11} Weed free	-	0.0	(1.0)	0.0	(1.0)	0.0	(1.0)	0.0	(1.0)	0.0	
C.D. (at 5%)			0.44		0.43		0.61		1.49		4.09
DAS – days after sowing, O – original values, T- $\sqrt{(x+1)}$ transformed values											

par with weed free treatment. The lowest dry matter of weeds recorded among the herbicide treatments in 2,4-D (Ethlyl estrer) + carfentrazone was statistically at par with 2,4-D (Na salt) + carfentrazone and metsulfuron + carfentrazone + surfactant. However, at harvest, the lowest weed dry matter recorded in metsulfuron + carfentrazone + surfactant was significantly higher than 2,4-D (Na salt/Ethlyl estrer) treatments but statistically at par with rest of the treatments. The new herbicide halauxifen + florasulam was also effective in controlling the weeds. The lower weed dry matter recorded in all the treatments was due to better weed control in these treatments as the weed density was low in these treatments. Mitra *et al.,* (2019) also found that halauxifen + florasulam was effective in controlling the weeds.

The weed control efficiency depicted the comparative performance of the herbicides. The higher weed control efficiency recorded in metsulfuron + carfentrazone + surfactant was statistically at par with 2,4-D (Ethlyl estrer) + carfentrazone and carfentrazone alone (Table 2). It was due to better weed control in these treatments. Ram and Singh, (2009) also found carfentrazone as an effective herbicide for controlling broadleaf weeds in barley. Singh *et al.,* (2011) also reported that premix carfentrazone+

Table 2: Effect of weed control treatments on weed control efficiency, herbicide efficiency index and wed index.

Treatment	Dose (g a.i./ha)	Weed control efficiency (%)	Herbicide efficiency index		Weed Index	
T_1 Halauxifen + florasulam + Poly	12.75	67.5	10.4	(2.15)	0.07	(1.03)
T_2 Metsulfuron + surfactant (S)	4	36.8	9.9	(1.99)	0.26	(1.11)
T_3 Carfentrazone	20	78.0	24.4	(2.97)	0.05	(1.02)
T_4 2,4-D Na (Na salt)	500	27.3	5.2	(1.54)	0.27	(1.12)
T_5 2,4-D EE (Ethyl ester)	500	45.4	6.0	(1.62)	0.25	(1.11)
T_6 Metsulfuron + carfentrazone +S	4+20	87.3	25.0	(3.08)	0.03	(1.01)
T_7 2,4-D Na + carfentrazone	400+20	82.7	16.3	(2.72)	0.05	(1.02)
T_8 2,4-D EE + carfentrazone	400+20	83.5	28.2	(3.19)	0.04	(1.02)
T_9 Halauxifen + florasulam+ carfentrazone + S	10.21+20	67.7	10.9	(2.16)	0.07	(1.03)
T_{10} Weedy check	-	-	-	-	0.63	(1.27)
C.D. (at 5%)		9.56		0.75		0.03

Table 3: Effect of weed control treatments on plant height, yield attributes, grain yield and biological yield of wheat.

Treatment	Dose (g a.i./ha)	Plant height (cm)	Effective tillers (no. /m^2)	1000-grain weight	Grains per earhead	Grain yield (q/ha)	Biological yield (q/ha)
T_1 Halauxifen + florasulam + Poly	12.75	91.8	402.2	44.1	36.0	63.73	164.02
T_2 Metsulfuron + surfactant (S)	4	91.1	361.3	42.9	32.3	49.45	141.67
T_3 Carfentrazone	20	92.4	404.4	44.5	36.6	65.07	166.05
T_4 2,4-D Na (Na salt)	500	91.1	350.2	41.4	34.3	49.02	153.54
T_5 2,4-D EE (Ethyl ester)	500	92.4	360.8	43.7	32.0	50.21	159.25
T_6 Metsulfuron + carfentrazone +S	4 + 20	90.9	409.3	45.1	36.2	66.25	169.89
T_7 2,4-D Na + carfentrazone	400 + 20	91.5	396.2	44.5	36.8	64.77	164.05
T_8 2,4-D EE + carfentrazone	400 + 20	93.0	407.7	44.2	36.9	66.06	170.14
T_9 Halauxifen + florasulam+ carfentrazone + S	10.21 + 20	93.5	392.9	44.2	36.7	63.55	159.05
T_{10} Weedy check	-	94.6	332.5	38.4	19.2	24.30	91.56
T_{11} Weed free	-	92.1	413.3	45.6	36.6	68.63	172.99
C.D. (at 5%)		NS	18.7	3.7	3.9	5.42	13.65

metsulfuron was effective for broadleaf weed control in wheat. The herbicide efficiency index recorded in 2,4-D (Ethlyl estrer) + carfentrazone was the highest which was statistically at par 2,4-D (Na salt) + carfentrazone, metsulfuron + carfentrazone + surfactant and carfentrazone alone. The weed index recorded in halauxifen + florasulam + surfactant was the highest, which was significantly higher than 2,4-D (Ethlyl estrer), metsulfuron + surfactant and weed free treatment. Similar finding are also recorded by Mitra *et al.,* (2019).

Yield attributes and grain yield

The highest yield attributes were recorded in weed free treatment (Table 3). Weedy check recorded the lowest effective tillers which was statistically at par similar to 2,4-D (Na salt) but significantly lower than all other herbicides. Weed free treatment recorded 24.3% higher effective tillers than recorded in weedy check treatment. The effective tillers recorded in weed free treatment was statistically at par 2,4-D (Na salt/Etyl ester) + carfentrazone, halauxifen + florasulam + carfentrazone + surfactant, metsulfuron + carfentrazone + surfactant, carfentrazone and halauxifen + florasulam + poly but was significantly higher than rest of the treatments. The higher effective tillers in the treatments was due to better weed control which provided the more space to the crop for increasing the tillers. The 1000-grain weight recorded in weed free treatment was the highest which was 18.8% higher than recorded in weed check and was statistically at par with all other treatments except 2,4-D (Na salt). The better weed control in the herbicide treatments was due to less competition between crop and weed which helped to improve the 1000-grain weight. Better yield attributes due to control of weeds with herbicides also reported by Ram and Singh, (2009) in barley and Shakya and Dixit, (2017) in wheat.

The grain yield is the net product of all the yield attributes and environmental conditions. The grain yield in weedy check was reduced to 64.6% as compared to weed free treatment. All the weed control treatments recorded significantly higher grain yield than weedy check treatment. The highest grain yield reordered in weed free treatment was statistically at par similar to 2,4-D (Na salt/Etyl ester) + carfentrazone, halauxifen + florasulam + carfentrazone + surfactant, metsulfuron + carfentrazone + surfactant, carfentrazone and halauxifen + florasulam + poly. As the major population of weeds was *Malva neglecta*, so the poor effectiveness of 2,4-D and metsulfuron treatments recorded (Table 1) although the combinations of 2,4-D/metsulfuron + carfentrazone were found to be effective in controlling weeds and increasing the grain yield. Among the herbicide treatments, 2,4-D + carfentrazone recorded the highest grain yield which was 171.8% higher than weedy check but 3.9% less than weed free treatment. The new herbicide halauxifen + florasulam + poly was equally effective as carfentrazone. Mitra *et al.,* (2019) also observed halauxifen + florasulam effective in controlling braod leaf weeds in Eastern Indian conditions. The relationship of grain yield and weed dry matter explained by the equation Y= -0.159X+ 74.25

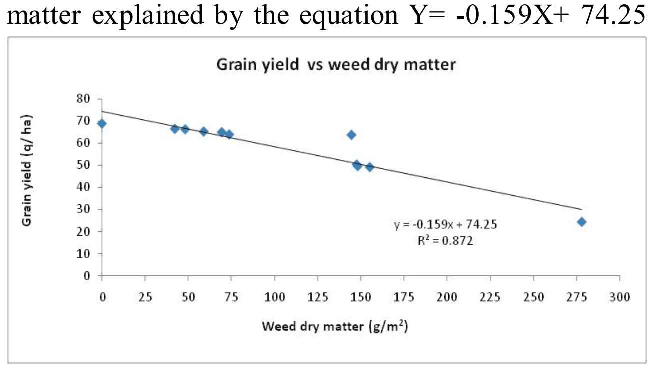

Fig. 1: Relationship between grain yield and weed dry matter across different treatments.

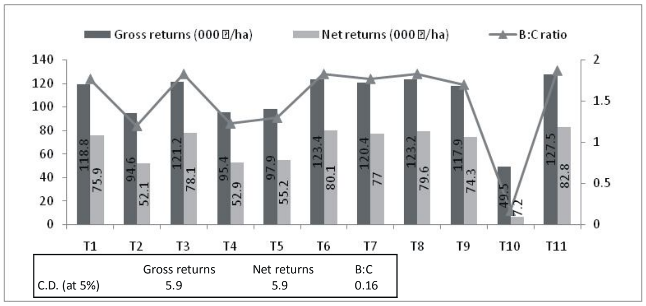

Fig. 2: Gross returns, net returns and benefit cost ratio (B:C) of different treatments as per table 1.

where Y is grain yield (q/ha) and X is weed dry matter (g/m^2) with R^2 value of 0.872 (Fig. 1).

All the herbicide treatments recorded significantly higher biological yield than weedy check treatment. The biological yield recorded in halauxifen + florasulam + ploy, carfentrazone, metsulfuron + carfentrazone and 2,4-D (Na salt/Etyl ester) + carfentrazone was statistically at par the weed free treatment. The minimum biological yield was recorded in weedy check (91.86 q/ha). Weed free treatment recorded 85.6% higher biological yield than weedy check treatment. It was due to better weed control which helped the crop to accumulate more dry matter. Chokkar *et al.,* (2015) also reported better grain and biological yield in wheat by using herbicides.

Economics

The weeds causes the maximum loss in gross returns, net returns and B:C ratio. Gharde *et al.,* (2018) also recorded significant economic looses in wheat due to weeds. The maximum gross returns, net returns and B:C ratio were recorded in weed free treatment (Fig. 2). It was due to higher grain yield recorded in weed free treatment. The gross returns recorded in weed free treatment was statistically at par with than 2,4-D (Ethlyl estrer) + carfentrazone. The gross returns recorded in 2,4-D (Ethlyl estrer) + carfentrazone was statistically similar to all the herbicides combinations except 2,4-D (Ethlyl estrer), 2,4-D (Na salt), metsulfuron + surfactant. It was due to similar weed control and grain yield recorded in these treatments. The net returns recorded in weed free was similar to metsulfuron + carfentrazone + surfactant and carfentrazone. Among the herbicide treatments net returns and B:C recorded in metsulfuron + carfentrazone + surfactant was similar to all the herbicides combinations except alone application of 2,4-D (Ethlyl estrer), 2,4-D (Na salt) and metsulfuron + surfactant. All the herbicides treatments recorded significantly higher B:C ratio than weedy check treatment.

Conclusions

The new herbicide halauxifen + florasulam + ployglycol (12.76 g/ha) or halauxifen + florasulam + carfentrazone + surfactant (10.21 + 20g/ha) are equally effective in controlling the broadleaf weeds, producing grain yield and economics as recoded in cafentrazone or its combination with other herbicides. With the introduction of this new herbicide more alternatives will be available with farmers for broadleaf weed control in wheat.

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