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Research Article

Evaluation of Herbicides and their Mixtures for Control of Broad Leaf Weeds in Wheat and their Economics

A.F. Nekhat, A.K. Dhaka, Bhagat Singh, Amit Kumar* and Ram Prakash

CCS Haryana Agricultural University, Hisar, Haryana, India

*Corresponding Author E-mail: amitsodhi1986@gmail.com

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ABSTRACT

Wheat is the main winter cereal crop of north-west India and in Haryana state. Weeds are considered to be the most distorted of crop production and account for ~1/3rd of total losses caused by all pests. Among numerous approaches have been in practice for handling the problem of weed infestation, chemical weed control seems indispensable and has proved efficient in controlling weeds. In order to evaluate the herbicides and their mixtures for control of broad leaf weeds in wheat and their economics, a field experiment was conducted at Research Farm area of CCS Haryana Agricultural University, Hisar during growing season of rabi 2018-19. Results promised that among herbicides and their mixtures aclonifen 500 + diflufenican 100 SC @ 1750 + 1750 g/ha closely followed by halauxifen-methyl + florasulam + carfentrazone + surfactant @ 24.99 + 50 + 750 g/ha with maximum weed control efficiency which severely reduced density and dry weight of broad-leaf weeds (Chenopodium album, Rumex dentatus, Anagallis arvensis, Medicago denticulate, Melilotus indicus and Lathyrus aphaca), while poor weed control treatments were recorded with application of 2,4-D NA (80 WP) and 2,4-D Ester (38 EC) @ 625 and 1316 g/ha. Hence highest net returns (Rs. 65,733 ha^{-1}) and B: C (1.82) recorded by application of aclonifen 500 + diflufenican 100 SC which were 0.13, 4.6 and 3.4 percent higher than weed free and 47.1, 193.7 and 41.1 percent higher than weedy check, respectively.

Keywords*: *Broad-leaf weeds, Economics, Herbicide mixtures, Weed control and Wheat.

INTRODUCTION

Wheat is the main winter cereal crop of north-west India and in Haryana state. The area, production and productivity of wheat in India is 29.58 m ha, 99.7 m tones and 3370.5 Kg/ha, respectively. Weeds are the most omnipresent class of pests that interfere with crop plants through competition and allelopathy, resulting in direct loss to quantity and quality of the product (Gupta, 2004) and indirectly increasing production costs including costs of labor, equipment, chemical and other management input (Singh et al., 2011a). The weed flora of wheat consists of both grassy and broad leaf weeds and if uncontrolled, they interfere with crop growth by competing for available nutrient, light and water (Jeet et al., 2010).

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Weeds are considered to be the most distorted of crop production and account for ~1/3rd of total losses caused by all pests (Chhokar et al., 2012). Major weeds associated with wheat are *Phalaris minor, Avena spp., Chenopodium album, Melilotus spp., Anagallis arvensis, Vicia sativa, Lathyrus aphaca and Rumex dentatus.* In recent years, a new species *Rumex sp*. has emerged as serious problem in irrigated wheat eco-system (Singh et al., 2011b). In India it has been estimated that out of total yield losses caused by the pests in wheat, weeds account ~33% and extent of yield reduction largely depends on growth and behavior of individual weed species in relation to agroecological condition.

Numerous approaches have been in practice for handling the problem of weed infestation such as hoeing, weeding, tillage, harrowing, crop rotation biological and chemical control. Chemical weed control seems indispensable and has proved efficient in controlling weeds (Kahramanoglu & Uygur, 2010) and hence currently about two-third, by volume of the pesticides used worldwide in agricultural production are herbicides. Indiscriminate use of herbicides for weed control during the past few decades has resulted in serious ecological and environmental problems, such as resistance, shifts in weed populations that are more closely related to the crops that they infest, minor weeds becoming dominant Heap (2007) and greater environmental and health hazards Rao (2000). Continuous application of a similar herbicide or use of lower than recommended dose led to development of herbicide resistance (Yadav et al., 2013). Herbicides with differential selectivity can be applied sequentially, but it involves application in two rounds, resulting in enhancing the cost. Therefore, mixing two different herbicides and applying them simultaneously widens the spectrum of weed-control, saves time, application cost and application rate.

Therefore, a need remains to evaluate new herbicides with different modes of action to tackle the ever increasing problem of complex weed flora. Keeping these points in view, it was planned to carry out a field experiment on evaluation of herbicides and their mixtures for control of broad leaf weeds in wheat and their economics.

MATERIALS AND METHODS

An experiment to evaluate herbicides and their mixtures for control of broad leaf weeds in wheat and their economics was conducted at Research Area of CCS Haryana Agricultural University, Hisar, (29°10' N latitude, 75° 46' E longitude and 215.2m amsl) in Haryana State of India during growing season of *rabi* 2018-19. Soil of experiment field was sandy loam in texture, low in nitrogen and medium in P_2O_5, K_2O and organic carbon with slightly alkaline pH of 7.6 in reaction and three years field crop history fallow-wheat, cotton-wheat, fallow-mastured and sorghum- experimental crop (wheat). The experiment was laid out in randomised block design using twelve post emergence herbicides (sole and their mixture) treatment combinations i.e Halauxifen-methyl ester + florasulam 40.85%WG + polyglycol 26-2N (0.25% v/v) @ 31.23 + 750 g/ha; metsulfuron-methyl 20 WP + 0.25% NIS surfactant @ 20 + 625 g/ha; carfentrazone ethyl 40DF @ 50 g/ha, 2, 4-D Na (80WP) @ 625 g/ha; 2, 4-D Ester (38 EC) @ 1316 g/ha; metsulfurone-methyl 10% WP + carfentrazone 40DF + 0.2% surfactant @ 20 + 50 + 625 g/ha; 2,4-D Na + carfentrazone @ 500 + 50 g/ha; 2,4-D Ester + carfentrazone @ 1053 + 50 g/ha; halauxifen-methyl + florasulam + carfentrazone + surfactant @ 24.99 + 50 + 750 g/ha; aclonifen 500 SC @ 2000 g/ha; diflufenican 100 SC @ 2000 g/ha; aclonifen 500 + diflufenican 100 SC @ 1750 + 1750 g/ha; weedy check and weed free, replicated thrice.

Sowing of variety WH 1105 was done by seed drill and machine as per treatments at 5-6 cm depth using 100 kg seed ha^{-1} and layout was performed. Fertilizer (NPK) was applied based on recommended dose. Nitrogen was applied at the rate of 150 kg ha-1 in two splits i.e. ½ at sowing and ½ at first irrigation while full dose of Phosphorus (P2O5) and Potassium (K2O) were applied at the time of sowing at the rate of 60 kg ha-1 each. Phosphorous was applied through di-ammonium phosphate. The amount of nitrogen after deducting from the availability of diammonium phosphate was applied in the form of urea. Potash was applied through muriate of potash. Herbicides of particular doses were sprayed alone or tank mixed by knap sack sprayer fitted with flat fan nozzle with 500 liter water per hectare after 35 DAS. Other cultural practices were followed as per requirement of the treatment and crop according to recommended package of practice.

Observations related to weed density, weed dry matter and weed control efficiency were recorded adopting the standard procedure at 30 DAS, 30 and 60 DAT and at maturity per mrl, the results were statistically analyzed. The density of broad leaf weeds was determined by quadrate method (Misra & Puri, 1954). The quadrate (1.0 m^{-2}) was thrown randomly at a place in each plot at 30 days after sowing and 30 and 60 days after spraying and at harvest. The weeds inside the quadrate were counted and the average of two quadrates was converted to plants m^{-2}. The weeds present within the quadrate from a place selected at random from each plot were taken for dry matter accumulation at different interval of observation taken. Weed control efficiency was calculated as per formula given below:

$$\text{WCE}\ (\%) = \frac{W_2 - W_1}{W_2} \times 100$$

Where,

W_2 = Dry weight of weeds in weedy plot

W_1 = Dry weight of weeds in treatment plot

RESULTS AND DISCUSSION

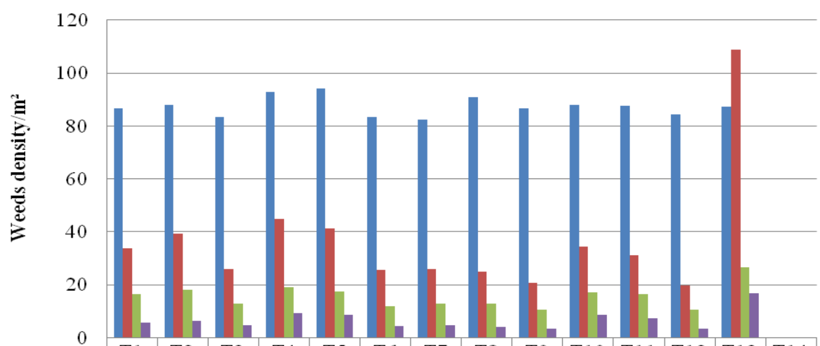
Major broad-leaf weed flora observed during the crop season in the experimental plots comprised *Chenopodium album, Rumex dentatus, Anagallis arvensis, Medicago denticulate*, *Melilotus indicus* and *Lathyrus aphaca* various herbicidal treatments exerted significant effect density and dry weight of weeds, weed control efficiency and its economics.

Effect on density of broad-leaf weeds

Highest density of broad-leaf weeds were observed in weedy check plot as weeds grow luxuriously and uninterrupted in the absence of any weed control practices throughout the crop growing season. Weed density in weedy check plot were significantly higher in comparison to other weed control treatments. Similar results were reported by Shehzad et al. (2012) and Hashim et al. (2002) who found that maximum weed population recorded in the weedy check plot in an herbicide trial on wheat. The number of broad-leaf weed population per mrl significantly reduced after application of herbicidal treatments which recorded at 30 and 60 DAT and at maturity. All herbicides and their mixtures were found effective in controlling broad-leaf weeds in wheat field Table 1 and Fig 1. Aclonifen 500 + diflufenican 100 SC was recorded with significantly lower weed density compared to different herbicides and their mixtures except carfentrazone- ethyl 40 DF, metsulfuron-methyl 10 % WP + carfentrzone 40 DF + 0.2 % surfactant, 2,4-D Na/Ester + carfentrazone and halauxifen-methyl + florasolam + carfentrazon + surfactant at all the stages of observation up to maturity. Aclonifen 500 + diflufenican 100 SC was recorded with 4.53, 3.41 and 1.99/m^2 at 30, 60 days after treatment and at maturity, respectively with 56.7, 34.9 and 52.2 percent lower than weedy check respectively at 30, 60 DAT and at maturity and it was closely followed by halauxifen-methyl + florasolam + carfentrazon + surfactant. Chhokar et al. (2007) reported similar results and described that herbicide mixture effectively controlled weeds compared to weedy check. Punia et al. (2017), Barla et al. (2017) and Meena et al. (2017) reported similarly that the superiority of tank mix application of broad-leaf weeds and grassy weeds suppressing herbicides over their individual applications in reducing total weed density. Density of *Convolvulus arvensis* were significantly reduced by treatments which contain carfentrazone i. e. Carfentrazone-ethyl 40DF @ 50 g/ha, metsulfuron-methyl 10 % WP + carfentrazone 40 DF + 0.2 % surfactant, 2,4-D Na/Ester + carfentrazone and halauxifen-methyl + florasolam + carfentrazon + surfactant compared to other treatments.

Effect on dry matter accumulation (DMA) of broad-leaf weeds

Different weed control treatments exerted significant influence on dry matter accumulation (DMA) in comparison to weedy check after the application of herbicidal treatments. At 30 DAS stages regarding dry matter accumulation of total broad-leaf weeds non significant differences were recorded among different herbicide treatments compared to weedy check, because herbicide treatments were imposed at 35 DAS stage. At 30 days after treatment application dry matter accumulation of weeds were significantly affected by various herbicide treatments (Table 1). Aclonifen 500 + diflufenican 100 SC was recorded with significantly lower dry matter accumulation of bread-leaf weeds compared to different herbicides and their mixtures except carfentrazone-ethyl 40 DF, metsulfuron-methyl 10 % WP + carfentrzone 40 DF + 0.2% surfactant, 2,4-D Na/Ester + carfentrazone and halauxifen-methyl + florasolam + carfentrazon + surfactant at all the stages of observation up to maturity. Aclonifen 500 + diflufenican 100 SC was recorded with 3.56, 2.38 and 1.81/m^2 at 30, 60 days after treatment and at maturity, respectively with 53.3, 45.7 and 47.5 percent lower than weedy check respectively at 30, 60 DAT and at maturity and it was closely followed by halauxifen-methyl + florasolam + carfentrazon + surfactant. Population and dry matter accumulation of weed species grassy and broad-leaf weeds were reduced drastically with the use of herbicides (Sharma et al., 2018).



	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14
30 DAS	86.7	88	83.3	92.7	94	83.3	82.3	91	86.7	88	87.7	84.3	87.3	0
30 DAT	33.7	39.3	26	44.7	41.3	25.7	26	25	20.7	34.3	31	19.7	109	0
60 DAT	16.4	18	13	19	17.3	12	12.7	12.7	10.7	17	16.4	10.7	26.7	0
Maturity	5.7	6.3	4.6	9.3	8.7	4.5	4.7	4	3.4	8.7	7.3	3.3	16.7	0

Fig. 1: Density of broad-leaf weeds/m^2

Supporting findings were also reported by Narial et al. (2008) and Meena and Singh (2011). Similar founding reported by Zhang et al. (1995) that application of two or more herbicides simultaneously either using post mixtures or by mixing different herbicide products before the application is very common approach in intensive agriculture. Dry weight of *Convolvulus arvensis* were reduced significantly by treatments which contain carfentrazone, i. e. Carfentrazone-ethyl 40DF @ 50 g/ha, metsulfuron-methyl 10 % WP + carfentrazone 40 DF + 0.2 % surfactant, 2,4-D Na/Ester + carfentrazone and halauxifen-methyl + florasolam + carfentrazon + surfactant compared to other treatments.

Weed control efficiency

All the herbicides and their mixtures recorded with higher weed control efficiency compared to weedy check plot at all the observation stages up to maturity (Table 2). Similar results were reported by Shehzad et al. (2012) and Hashim et al. (2002) who found that maximum weed population recorded in the weedy check plot in an herbicide trial on wheat. Chhokar et al. (2007) reported similar results and described that herbicide mixture effectively controlled weeds compared to weedy check. Among the herbicides and their mixtures, Aclonifen 500 + diflufenican 100 SC was recorded with higher weed control efficiency closely followed by halauxifen-methyl + florasolam + carfentrazon + surfactant at all observation stages, while application of 2,4-D Na (80 WP) and 2,4-D Ester (38 EC) was recorded with lower weed control efficiency. Aclonifen 500 + diflufenican 100 SC was recorded with higher weed control efficiency 79.4, 73.4 and 71.1 percent at 30, 60 DAT and at maturity, respectively which were 79.4, 73.4 and 71.1 percent higher than weedy check plot.

Economics

The economics of various treatments had been estimated for comparison and to find out the most economical herbicide treatment for control of broad-leaf weeds in wheat. Among all the herbicides and their mixtures tested in study (Table 2), aclonifen 500 + diflufenican 100 SC @ 1750 + 1750 g/ha was recorded with higher economics closely followed by halauxifen – methyl + florasulam + carfentrazone + surfactant @ 24.99 + 50 + 750 g/ha. Aclonifen 500 + diflufenican 100 SC @ 1750 + 1750 g/ha was recorded with higher cost of cultivation (Rs. 79,915 ha^{-1}) which was 3.7 percent lower than weed free and 4.3 percent higher than weedy check. Among the different herbicides and their mixtures, application of aclonifen 500 + diflufenican 100 SC @ 1750 + 1750 g/ha was recorded with maximum gross return (Rs. 145,648 ha^{-1}), net return (Rs. 65,733 ha^{-1}) and B:C (1.82) which were 0.13, 4.6 and 3.4 percent higher than weed free and 47.1, 193.7 and 41.1 percent higher than weedy check, respectively. Similar findings were given by Ashrafi et al. (2009), who reported that broad spectrum herbicides gave maximum net return in wheat and minimum net return was received in weedy check. Similarly Kamrozzaman et al. (2015) and Singh and Gosh (1992) described that weed control in wheat through herbicides are more economical than hand weeding.

Table 1: Effect of herbicides and their mixtures on density and dry matter accumulation (DMA) of broad-leaf weeds in wheat

Treatments	Dose (g/ha)	30 DAS		30 DAT		60 DAT		Maturity	
		Density No./mrl	DMA g/mrl	Density No./mrl	DMA g/mrl	Density No./mrl	DMA g/mrl	Density No./mrl	DMA g/mrl
Halauxifen-methyl ester + florasulam 40.85%WG + polyglycol 26-2N (0.25 % v/v)	31.23 + 750	9.36 (86.7)	5.28 (26.9)	5.87 (33.7)	4.26 (17.3)	4.17 (16.4)	3.81 (7.3)	2.57 (5.7)	2.44 (4.9)
Metsulfuron-methyl 20 WP + 0.25 % surfactant	20 + 625	9.43 (88.0)	5.46 (29.0)	6.34 (39.3)	4.55 (19.7)	4.35 (18.0)	4..04 (15.4)	2.7 (6.3)	2.52 (5.4)
Carfentrazone-ethyl 40 DF	50	9.18 (83.3)	5.44 (28.7)	5.18 (26.0)	4.19 (16.7)	3.72 (13.0)	2.78 (7.0)	2.37 (4.6)	2.29 (4.4)
2, 4-D Na (80WP)	625	9.68 (92.7)	5.43 (29.1)	6.74 (44.7)	4.96 (23.7)	4.39 (19.0)	3.3 (10.0)	3.18 (9.3)	2.72 (6.5)
2, 4-D Ester (38 EC)	1316	9.75 (94.0)	5.44 (29.0)	6.49 (41.3)	4.63 (20.7)	4.28 (17.3)	3.04 (8.7)	3.1 (8.7)	2.54 (5.7)
Metsulfuron-methyl 10 % WP + carfentrazone 40 DF + 0.2 % surfactant	20 + 50 + 625	9.18 (83.3)	5.44 (28.8)	5.16 (25.7)	4.08 (15.7)	3.6 (12.0)	2.71 (6.5)	2.35 (4.5)	2.25 (4.2)
2, 4-D Na + carfentrazone	500 + 50	9.13 (82.3)	5.64 (31.0)	5.19 (26.0)	4.1 (16.0)	3.69 (12.7)	2.69 (6.7)	2.37 (4.7)	2.26 (4.4)
2, 4-D Ester + carfentrazone	1053 + 50	9.59 (91.0)	5.62 (30.6)	5.08 (25.0)	4.08 (15.7)	3.68 (12.7)	2.71 (6.5)	2.23 (4.0)	2.26 (4.2)
Halauxifen-methyl + florasulam + carfentrazone + surfactant	24.99 +50 + 750	9.36 (86.7)	5.39 (28.2)	4.65 (20.7)	3.85 (14.0)	3.4 (10.7)	2.53 (5.8)	2.1 (3.4)	2.1 (3.7)
Aclonifen 500 SC	2000	9.43 (88.0)	5.43 (28.6)	5.94 (34.3)	4.49 (19.3)	4.22 (17.0)	2.99 (8.0)	3.07 (8.7)	2.48 (5.4)
Diflufenican 100 SC	2000	9.42 (87.7)	5.67 (31.4)	5.63 (31.0)	4.3 (16.3)	4.17 (16.4)	2.98 (6.7)	2.83 (7.3)	2.55 (5.5)
Aclonifen 500 + diflufenican 100 SC	1750 + 1750	9.23 (84.3)	5.71 (31.6)	4.53 (19.7)	3.56 (11.8)	3.41 (10.7)	2.38 (4.9)	1.99 (3.3)	1.81 (2.3)
Weedy check	--	9.39 (87.3)	5.39 (28.1)	10.47 (109)	7.62 (57.3)	5.24 (26.7)	4.38 (18.2)	4.16 (16.7)	3.45 (11.0)
Weed free	--	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
SEm±		0.14	0.25	0.27	0.21	0.26	0.2	0.12	2.0
CD at 5%		N.S	N.S	0.79	0.64	0.75	0.61	0.39	0.59

Original data given in parenthesis was subjected to square root($\sqrt{x+1}$) transformation before analysis

Table 2: Effect of herbicides and their mixtures on weed control efficiency and economics

Treatments	Dose (g/ha)	Weed control efficiency (%)				Economics			
		30 DAS	30 DAT	60 DAT	Maturity	Cost of cultivation (`Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B: C
Halauxifen-methyl ester + florasulam 40.85%WG + polyglycol 26-2N (0.25 % v/v)	31.23 + 750	-	69.8	60.1	57.4	77,847	131,928	54,081	1.69
Metsulfuron-methyl 20 WP + 0.25 % surfactant	20 + 625	-	65.7	54.5	51.1	77,357	130,193	52,836	1.68
Carfentrazone-ethyl 40 DF	50	-	70.9	61.7	59.8	77,657	131,733	54,076	1.70
2, 4-D Na (80WP)	625	-	58.7	44.9	40.5	77,357	123,360	46,003	1.59
2, 4-D Ester (38 EC)	1316	-	64.0	52.0	47.6	77,407	125,372	47,965	1.62
Metsulfuron-methyl 10 % WP + carfentrazone 40 DF + 0.2 % surfactant	20 + 50 + 625	-	72.7	64.4	62.1	77,907	142,713	64,806	1.79
2, 4-D Na + carfentrazone	500 + 50	-	72.1	63.5	60.3	77,857	135,177	57,320	1.74
2, 4-D Ester + carfentrazone	1053 + 50	-	72.7	64.3	61.5	77,897	136,272	58,375	1.75
Halauxifen-methyl + florasulam + carfentrazone + surfactant	24.99 +50 + 750	-	75.6	68.3	66.6	79,306	144,694	65,388	1.80
Aclonifen 500 SC	2000	-	66.3	55.4	51.1	79,077	131,087	52,010	1.66
Diflufenican 100 SC	2000	-	72.1	63.4	60.6	78,837	134,642	55,805	1.71
Aclonifen 500 + diflufenican 100 SC	1750 + 1750	-	79.4	73.4	71.1	79,915	145,648	65,733	1.82
Weedy check	--	0.0	0.0	0.0	0.0	76,607	98,988	22,381	1.29
Weed free	--	100	100.0	100.0	100.0	83,007	145,844	62,837	1.76

CONCLUSION

Based on field research experiment, it is concluded that among all the herbicides and their mixtures tested, application of aclonifen 500 + diflufenican 100 SC @ 1750 + 1750 g/ha at 35 DAS was found most effective against broad-leaf weeds except *Convulus arevensis* in wheat and it was also recorded with significantly lower weed density and weed dry matter accumulation and higher weed control efficiency (71.1 %), net returns (65,733 Rs./ha) and B:C (1.82) at harvesting, which were 52.2 and 47.5 lower than weedy check and 71.1, 193.7 and 41.1 percent higher than weedy check plot, respectively.

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