Research Article

Effect of herbicides mixture on productivity and Profitability of wheat (*Triticum aestivum* L.) cultivation in rainfed subtropics of Jammu region

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ABSTRACT

Wheat (Triticumaestivum L.) is the second most important staple crop in India after rice. Weeds have emerged as the major biotic stress in wheat. Post-emergence herbicidal combinations are used widely to control the complex weed flora in wheat crops. Over the past decades, micronutrient deficiency has emerged as a major constraint in wheat production, especially zinc and iron. The field experiment was conducted at KVK, Reasi, J&K, during the Rabi season of 2018-19. The experiment was conducted in a randomized block design having three replications; each having seven treatments. Weedy check and weed-free were maintained throughout the experiment. The Weed control efficiency (%) and weed index was calculated from the yield of weed-free and respective treatment yield. Economic evaluation was made in terms of gross returns, net returns, and benefit-cost ratio. Results of the experiment revealed that the application of Pinoxaden + Carfentrazone @ 50 +20 gha-1 was the most effective herbicidal combination among the tested herbicidal combinations and yielded the lowest weed index 4.34 and highest weed control efficiency 91.54%. Whereas,Weed free produced significantly the highest grain yield of 3883 kg ha-1 and straw yield of 5323 kg ha-1 respectively. In the case of economics common cost of cultivation for growing a wheat crop was comes out to 25568.46/ha-1 and the highest cost of cultivation was recorded in weed-free 31568.46 /ha-1, highest net return 63453.59 ha-1 under the treatmentSulfosulfuron + Metsulfuron 32 g ha-1 followed by Mesosulfuron + Iodosulfuron (62820.04).

Keywords: *Wheat; Weed Control Efficiency; Weedy Index; Herbicide mixture; Productivity; Profitability.*

INTRODUCTION

Wheat (*Triticumaestivum* L.) is one of the world's major cereal food crops and has a very important role in attaining food security. About 19 percent of the calories and 21 percent of the protein needs of humans are satisfied by wheat day by day on the planet (Braun et al., 2010). Because of its wide adaptability, it tends to become established under different agro-climatic conditions. It is grown on about 215 million hectares (MHA), with an annual production of about 700 million tonnes (mt) of wheat in the world (FAO, 2018). Besides this, the raise prediction of a decline in the cultivated area of wheat in India and China due to climate change (Nelson et al.,2010). The introduction of dwarf wheat varieties coupled with intensive input (assured irrigation and fertilizers) after the Green Revolution led to a complex problem. Wheat is infested by multifarious weed flora comprising both grassy as well as broad-leaved weeds causing yield reduction of 15–40% depending upon type and intensity of their infestation (Katara et al., 2012; Singh et al., 2012; Kumar et al., 2013). Weed competition is intense during the first 30-40 days after sowing the wheat crop. Herbicides continue to be the most powerful, economically effective, and reliable way to control weeds in wheat.

Many Pre-emergence viz., Pendimethalin and Post-emergent herbicides viz., 2,4-D and metsulfuron are recommended for effective weed control in wheat, but residues of these herbicides in soil restrict the choice of succeeding crops. Thus, it became important to evaluate new herbicide molecules for the management of weeds in wheat. Since no single herbicide controls both narrow and broad-leaved weeds, therefore, mixing of herbicides has shown great promise in controlling the complex weed flora of wheat.

Several new herbicides viz.,clodinafop, fenoxaprop, sulfosulfuron, carfentrazone, diclofop, pinoxaden, and pre-mix sulfosulfuron+metsulfuron, clodinafop+metsulfuron, carfentrazone+sulfosulfuron, clodinafop+metribuzin, fenoxaprop+metribuzin, and metsulfuron+carfentrazone have been found very effective in controlling weeds without any residual effect on succeeding crops as well as to prevent development of herbicide-resistant weeds in wheat (Chopra et al., 2015; Sharma et al., 2015; Pal et al., 2015).

The herbicidal combinations could be very effective against both grassy as well as broad-leaved weeds and help to reduce cost, time and labor. The herbicidal combinations could be very effective against both grassy as well as broad-leaved weeds and help to reduce cost, time and labor. For instance, the application of clodinafop + metsulfuron-methyl (15:1 ratio) @60 gha-1as tank mix provides excellent control of grassy as well as broad-leaved weeds in wheat (Punia et al., 2004). Ready-mix of clodinafop + metsulfuron @ (75 gha-1 + 0.2 % surfactant) reduces the density of the grassy and broadleaf weeds to very low level and results in a comparable level of wheat grain yield to sequential application of clodinafop @60gha-1and metsulfuron @4gha-1 and weed free, without any phytotoxicity symptoms on the crop (Kaur et al., 2015). Tank mix application of sulfosulfuron + metsulfuron can also be used for weed control in wheat without compromising weed control efficiency (Chhokar et al.,2007). Herbicidal combinations (ready mix) of clodinafop + metsulfuron (Vesta), sulfosulfuron + metsulfuron (Total), fenoxaprop + metribuzin (Accordplus) and mesosulfuron + iodosulfuron (Atlantis) are very effective (WCE>90%) in wheat Crop (Tiwari et al., 2016). A ready mix of mesosulfuron + iodosulfuron (24 + 4.8 gha-1) and sulfosulfuron + metsulfuron methyl (20 + 4.0 gha-1) provides a satisfactory level of weed control and has no adverse effect on wheat (Pal et al., 2016). Ready mix application of sulfosulfuron (75%) + metsulfuron-methyl (5%) WG (32 gha-1), clodinafop (15%) + metsulfuron-methyl (1%) WP (64gha-1) and mesosulfuron (3%) + iodosulfuron (0.6%) WDG (14.4gha-1) controls the weeds efficiently and effectively in wheat but tank mix of mesosulfuron (3 %) + iodosulfuron-methyl sodium (0.6 %WDG) shows phytotoxic effects on wheat also (Patel et al., 2017). Application of mesosulfuron + iodosulfuron (Atlantis) @ (12 + 2.4 gha-1) as well as clodinafop + metsulfuron (vesta) @ (60 + 4 gha-1) provides WCE of more than 85 per cent in wheat (Sasodeet al., 2017). So, herbicidal mixtures are very effective in controlling complex weed flora in wheat. Farmers will also be happier to use these tank mix herbicides in one go to save time, energy, and additional cost. However, very less information is available about the compatibility of herbicidal combinations.

MATERIAL AND METHODS

The field experiment was conducted at KVK, Reasi, Directorate of Extension, Sher-e-Kashmir University of Agricultural Sciences and Technology- Jammu (J&K UT) during the Rabi season of 2018–19. The Soil of the experimental site was neutral with a pH value of 7.02; EC (0.77) high in organic carbon (0.82); High N (562.95),P (29.68), K(325.52)sufficient in available sulfur (17.2), zinc (0.78ppm) available iron (6.48 ppm), Mn(3.62) and Cu (0.62). An experiment was laid out in Randomized Block Design (RBD) having 7 treatments, each having 3 replications. Wheat variety WH 1080 was sown as per recommendations. The Crop was raised with a recommended package of practices except for weed management. Treatments of weed management were applied at 35 days after sowing (DAS) in different plots of size 6.0 m x 2.2 m. Treatments consist of sole application off our herbicidal combinations viz. clodinafop + metsulfuron (60gha-1), sulfosulfuron + metsulfuron (32gha-1), mesosulfuron + iodosulfuron (14.4 gha-1), isoproturon +fenoxaprop250 g +45 g ha-1 and pinoxaden + carfentrazone (50 + 20 gha-1); rest two were weedy check and weed free.

A recommended dose of fertilizer through Urea, Diammonium phosphate, and Muriate of potash was applied before sowing as basal. A top dressing of 60 kg N ha-1 in form of Urea was applied at 25 days after sowing. The post-emergence spray was done at 35 DAS using a knapsack sprayer with a flood jet nozzle. The spray volume herbicide application was 500 L ha-1. The crop was raised as per the recommended package of practices. Growth and yield attributing characters viz., plant height, no. of effective tillers m-1 row length, no. of spikelets spike-1, no. of grains spike-1, and 100-seed weight were recorded at harvest. The crop was harvested from the net plot at maturity. The grains were separated from plants by thresher and grain and straw yields were recorded for each plot. The dry weight of weeds was recorded at harvest. Weed index (WI) and weed control efficiency (WCE) was worked out using the following formulae suggested by Gill and Kumar (1969); and Kondap and Upadhyay (1985).

X 100Weed control Efficiency; $WCE(\%): \frac{DW_C - DW_T}{Dwc} \times 100$

X 100Weed index (WI) : $\frac{Y_{WF} - Y_T}{Y_{WF}} \times 100$

Cost of cultivation of the crop (wheat) and the additive cost of each treatment were calculated by taking into account all the items per standard procedure and prevailing market rates. Both were added to get treatment -wise cost of cultivation. Gross returns were calculated by multiplying grain and straw yield (Kgha-1) with prevailing market rates and summing up both.
Net returns (Rs./ha) were determined by the formula:-
Net returns = Gross returns (Rs./ha)–Gross cost (Rs./ha)
Benefit-cost ratio was determined by the following formula:

$$\text{BC Ratio} = \frac{\text{Gross returns}}{\text{Cost of Cultivation}}$$

Statistical analysis of data

Data used in the study are the mean values of the replicated observations. All the experimental data for various crop parameters were statistically analyzed by the online computer program OPSTAT (Sheoran et al., 1998). The significance of the different treatment effects was tested with the help of, "F" (variance) test. To evaluate the significant difference between the means of the two treatments, the critical difference (C.D.) was worked out by the formula given below:

C.D.=(√2xEMS/n)×t value at 5%

Where,

C.D=critical difference

EMS=error mean sum of square

n= number of observations

t=value of t-distribution at 5% level of significance & error degree of freedom.

RESULTS AND DISCUSSION

The major weed flora noticed were Echinochloacolona, Cynodondactylon, Brachiaria spp. and Dactylocteniumaegyptium among the monocots; Amaranthusviridis, Chenopodium album, Digera arvensis, Melilotus indica, Portulaca oleracea, Convolvulus arvensis, Euphorbia hirta and Phyllanthusniruri among the dicot weeds and Cyperusrotundus as sedge weed.

Table 1: Effect of weed management on growth and yield attributes of wheat

Treatment	Dose(g ha-1)	Plant height (cm)	Effective tillers/m row length	Spikelets spike-1	Grains spike-1	100-seed weight (g)

T1 Clodinafop + Metsulfuron	60	86.17	70.33	12.45	27.12	42.23
T2 Sulfosulfuron + Metsulfuron	32	88.33	71.76	13.10	27.88	42.12
T3 Mesosulfuron + Iodosulfuron	14.4	88.06	71.32	13.12	28.37	43.17
T4 Isoproturon +Fenoxaprop	250 +45	82.97	68.12	12.24	27.32	41.56
T5 Pinoxaden + Carfentrazone	50 + 20	90.17	73.34	13.90	29.24	43.40
T6 Weed free		91.17	74.77	14.65	30.46	44.90
T7 Weedy check		70.53	51.50	9.16	21.14	37.34
SEm±		1.61	1.46	0.51	0.78	0.52
CD (p=0.05)		4.73	4.23	1.50	2.30	1.53

Effect on crop

Data presented in Table 1 showed growth and yield attributes *viz*., highest plant height, effective tillers m^{-1}row length, spikelets $spike^{-1}$, grains $spike^{-1}$and 100-seed weight were significantly the highest plant height (91.17 cm) was recorded under the weed-free check, however it remained statistically at par with Pinoxaden + Carfentrazone (90.17 cm), pre-mix sulfosulfuron + metsulfuron 32 g ha-1 at 30 DAS (88.33 cm) and pre-mix Mesosulfuron + Iodosulfuron (88.06)clodinafop+metsulfuron g ha^{-1}at 30 DAS (86.17 cm). Whereas, significantly the lowest plant height (70.53 cm) was registered under the weedy check.

The weed-free plot has significantly the highest number of effective tillers m^{-1}row length (74.77), however, it remained statistically at par with T2, T3 and T5, T1pre-mix Clodinafop + Metsulfuron60g ha^{-1}at 30 DAS (70.33) and T4pre-mix Isoproturon +Fenoxaprop 250 g + 45 g ha-1 at 30 DAS (68.12) has significantly lower no. of effective tiller among the chemical used in the experiment field. The weedy check has significantly the lowest number of effective tillers m^{-1}row length (51.50).

Effective control of weeds through manual weeding in the weed-free and pre-tank mix of T5 Pinoxaden + Carfentrazone 50+20 g ha^{-1} 30 DAS caused less crop-weed competition throughout the growth period of the crop, followed by T2 and T3 treatments and a same trend followed by the treatments in dry weight of weeds, which might have resulted in better availability of space, sunlight, moisture and nutrients to the crop in absence of weeds. Thus, increased water and nutrient uptake, which might have accelerated the photosynthetic rate, thereby increasing the supply of carbohydrates, resulted in cell division, multiplication and elongation leading to an increase in growth character. These results were in conformity with Katara et al. (2012); Pisal and Sagarka (2013); Singh et al. (2013).

Number of spikelets $spike^{-1}$ was significantly the highest (14.65) under the weed free treatment, but it was found statistically equivalent to T5 Pinoxaden + Carfentrazone30 DAS (13.90), However, rest of the treatments showed the trend T3>T2>T1 >T4 but were significantly at par with each other. Obviously, the weedy check registered significantly the lowest number of spikelets $spike^{-1}$(9.16).

Significantly the highest number of grains $spike^{-1}$(30.46) was observed under the weed-free plot, however it did not differ significantly from T5 and T3 and were at par with each other. T1 and T4 alsodid not differ significantly from other but significantly recorded lower no of grains $spike^{-1}$ Evidently, the weedy check recorded significantly the lowest no. of grains $spike^{-1}$(21.14).

The weed free treatment recorded significantly the highest test weight (44.90 g), which remained statistically at par with T5pre-mix Pinoxaden + Carfentrazone50 + 20 g ha-1 and T3 Mesosulfuron + Iodosulfuron 14.4 g ha-1 at 30 DAS. However, the rest of the treatments were significantly at par with each other except T7. Significantly the lowest test weight was noted with the weedy check (37.34 g).

Increased values in these yield attributes might have been on account of the overall improvement in vegetative growth which favorably influenced the tillering, flowering, and fruiting and ultimately resulted in increased effective tillers m-1 row length, spikelets spike-1, grains spike-1, and test weight. The results are parallel with those of Vyavahare (2012); Kumari et al. (2013); Punia et al. (2013); and Singh et al. (2015).

Table 2: Effect of weed management on crop yield and weed parameters

Treatment	Grain yield (kg ha-1)	Straw yield (kg ha-1)	Weed dry weight (kg ha-1)	Weed index (%)	Weed control efficiency (%)
T1 Clodinafop + Metsulfuron	3298	4196	545	12.86	78.45
T2 Sulfosulfuron + Metsulfuron	3632	4654	328	7.18	83.54

T3 Mesosulfuron + Iodosulfuron	3525	4459	294	7.23	84.34
T4 Isoproturon +Fenoxaprop	3110	4065	618	14.89	75.81
T5 Pinoxaden + Carfentrazone	3788	5093	231	4.34	91.54
T6 Weed free	3883	5323	30	0.00	98.29
T7 Weedy check	1987	2879	1757	48.73	0.00
SEm±	123	205	46	--	--
CD (p=0.05)	318	558	135	--	--

The data furnished in Table 2 showed the weed-free check produced significantly the highest grain yield of 3883 kg ha-1 and straw yield of 5323 kg ha-1. The next superior treatments in this regard were T5 where Pinoxaden + Carfentrazone @ 50 + 20 g ha^{-1} and T2 Sulfosulfuron + Metsulfuron @ 30 g ha^{-1} pre-tank mix applied at 30 DAS but were significantly at par with each other, However, T3 Mesosulfuron + Iodosulfuron 14.4 g ha^{-1} were significantly at par T2 and T5 but achieved registering significantly lower yield (3525 kg ha^{-1}) than weed free.T4 Isoproturon +Fenoxaprop application registering lowest grain yield 3110 and straw yield 4065 kg ha-1 but was significantly at apr with the application of T1 Clodinafop + Metsulfuron 3298 and 41 96 kg ha-1 grain and straw yield respectively. Weedy check registered as usual significantly lowest grain and straw yield 1987 and 2879 kg ha^{-1} respectively. These treatments increased seed yield by 95, 91, 83, and 77%, and straw yield by 84, 80, 77, and 71% over the weedy check, respectively. Removal of weeds by hand weeding in the initial stage and supplemented with herbicide application suppressed weeds, which in turn provided the better weed-free environment to the crop during the critical period for growth and development. These results are in conformity with the findings of Malik et al. (2012), Kaur et al. (2015), Pal et al. (2015); Singh et al. (2015).

Effect on weeds

The data (Table 2) indicated that the weed-free recorded significantly the lowest dry weight of weeds (30 kg ha-1), followed by T5 Pinoxaden + Carfentrazone @ 50 + 20 g ha-1 , T3 Mesosulfuron + Iodosulfuronand T2 Sulfosulfuron + Metsulfuronat 30 DAS having weed dry weight of 30, 231, 294 and 328 kg ha-1, WI of 0.00, 4.34, 718 and 7.23%, and WCE of 98.29, 91.54, 84.34 and 83.54%, respectively. Efficient control of weeds under these treatments has been reflected in the lower dry weight of weeds and evidently showed excellent weed indices. The results corroborate the findings of Yadav et al. (2011); Singh et al. (2013); Tiwari et al. (2015); Chaudhary et al. (2016).

Table 3 Economics of herbicidal combinations

Treatment	Dose(g ha-1)	Cost of Cultivation (Rs. ha-1)	Gross Returns (Rs. ha-1)	Net Returns (Rs.ha-1)	B:C
T1 Clodinafop + Metsulfuron	60	26843.46	79214.6	52371.14	2.04
T2 Sulfosulfuron + Metsulfuron	32	26908.46	90362.05	63453.59	2.48
T3 Mesosulfuron + Iodosulfuron	14.4	26328.46	89148.5	62820.04	2.45
T4 Isoproturon +Fenoxaprop	250 +45	26517.46	75914.05	49396.59	1.93
T5 Pinoxaden + Carfentrazone	50 + 20	27081.46	84990.55	57909.09	2.26
T6 Weed free		31568.46	91707.05	60138.59	2.35
T7 Weedy check		25568.46	64263.5	38695.04	1.51

Economics of Weed control

It is one of the very important concepts of any research work which indicates the profitability of a particular treatment. In this experiment, a common cost of cultivation for growing a wheat crop was calculated and its value came out to 25568.46/ha-1. Then the highest cost of cultivationwas recorded in weed free 31568.46 /ha-1, treatment, followed by Pinoxaden + Carfentrazone 50 + 20 g a.i ha-1 (T5), Sulfosulfuron + Metsulfuron 32 g a.i ha -1 (T2), Clodinafop + Metsulfuron 60 g a.i ha-1 (T1), Isoproturon +Fenoxaprop 250+ 45 g a.i ha-1 (T4) and Mesosulfuron + Iodosulfuron 14.4 g a.i ha-1 (T3), respectively, and lowest cost of cultivation was calculated in weedy treatment (25568.46/ ha-1). The highest gross return (91707.05) of ha-1 was obtained under the weed-free (T6), treatment followed by Sulfosulfuron + Metsulfuron 32g a.i ha-1(T2), (90362.05), Mesosulfuron + Iodosulfuron 14.4 g a.i ha-1

(T3), (89148.5), respectively. The lowest return (64263.5) was observed with the weedy treatment. This is because of less weed-crop competition for light, nutrients, space and moisture in weed control treatment plots as compared to the weedy treatment plots, which produced higher grain and straw yield from a given area. The lowest gross returns of (64263.5/ha-1) were accrued under weedy (T7) treatment due to more weed crop competition and the production of weak stature of a crop plant. Remarkably the highest net return63453.59 ha-1 was recorded under the treatment(T2), followed by Mesosulfuron + Iodosulfuron (62820.04) with the treatment (T3), because higher crop yield with minimum cost of cultivation.The net returns from weed-free treatment were wassomewhat lowest due their high weed control cost. Significantly the lowest net return (38695.04) with benefit-cost ratio of 1.51.

Conclusion

All the herbicidal combinations tested under study improve the productivity by improving the growth and yield attributing characters also improved the weed control efficiency WCE (%). Tank mixing of herbicides further lowered the weed index. Any treatment resulting in higher net returns could be evaluated as the best treatment, and in the current study, Sulfosulfuron + Metsulfuron(32 gha^{-1}) resulted in the highest net returns and benefit-cost ratio. Hence, it was adjudged to be the best treatment for control of complex weed flora in wheat than the other treatments.

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