RESEARCH ARTICLE

Effect of Post-Emergence Herbicidal Combinations Tank Mixed with Zinc or/and Iron Sulphate on Weed Index and Economics in Wheat Crop (*Triticum aestivum*)

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ABSTRACT

Wheat (*Triticum aestivum*) is second most important staple crop in India after rice. Weeds haveemerged as the major biotic stress in wheat. Post-emergence herbicidal combinations are used widely tocontrol the complex weed flora in wheat crops. Over the past decades, micronutrient deficiency has emergedas major constraint in wheat production, especially zinc and iron. The field experiment was conducted atRRS, Bawal, Haryana, during *Rabi* season of 2018-19. The experiment was conducted in a randomized block designhaving 3 replications; each having 18 treatments. Four herbicidal combinations were evaluated as sole andtank mixed with zinc or/and iron sulphate. Weedy check and weed free were maintained throughout theexperiment. The weed index was calculated from the yield of weed free and respective treatment yield. Economicevaluation was made in terms of gross returns, net returns, and benefit-cost ratio. Results of experiment revealed that application of mesosulfuron+iodosulfuron @14.4gha^{1} was most effective herbicidal combination amongthe tested herbicidal combinations and yielded lowest weed index. Tank mixing ofmicronutrients with herbicidal combinations further lowered down the weed index and even negative values were obtained. Tank mixing of herbicidal combinations with micronutrients was more economical than application of sole herbicidal combinations. Highest net returns and benefit cost ratio was recorded under mesosulfuron + iodosulfuron @ 14.4 gha^{-1} + $ZnSO_4$(0.5 %) + Urea (2.5 %) + $FeSO_4$(0.5 %) followed by sulfosulfuron+metsulfuron@32gha^{-1}+$ZnSO_4$ (0.5%) +Urea (2.5%)+$FeSO_4$ (0.5%).

Keywords: *Herbicida lcombinations; Micronutrients; Tank mixing; Weed index.*

INTRODUCTION

Wheat (*Triticum aestivum* 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 protein needs of human 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 Green Revolution led to the complex problem of both grassy and broad-leaved weeds. Major grassy weeds like *Phalaris minor* and *Avena ludoviciana*, and broad-leaved weeds like *Chenopodium album, Rumex dentatus, Angallis arvensis, Convolvulus arvensis, Fumaria parviflora, Malva parviflora* etc. are affecting wheat productivity in wheat growing areas of Haryana, Punjab, parts of Delhi, Uttarakhand Uttar Pradesh, along with states in north-western Indian Plains, and other wheat growing areas. Weed management is very important for achieving higher wheat production. Mechanical, cultural, biological, and chemical methods can be adopted for weed management in wheat (Chhokar *et al.*, 2012). Among these methods, chemical weed control is more efficient, less costly, and less time-consuming. However, herbicides are effective against some weed groups due to their mode of action, and they do not kill other weeds. To control other weeds, another herbicide is needed, which involves more

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cost, time and labor. To overcome this, herbicidal combinations are used. 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, application of clodinafop + metsulfuron-methyl (15:1 ratio) @60 gha^{-1}as 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 @60$gha^{-1}$and 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). 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 morethan 85 per cent in wheat (Sasode *et al*., 2017). So, herbicidal mixtures are very effective in controlling complex weed flora in wheat.

Another factor affecting wheat productivity and quality is imbalanced fertilization and deficiency of nutrients especially micronutrients. Zn and Fe are essential micronutrients for plants as well as human beings. They are involved in many enzymatic reactions and metabolic processes. Being a critical constituent of various enzymes, they play substantial role in basic biological processes like nitrogen fixation, energy transfer and protein synthesis, photosynthesis etc. (Rout and Sahoo, 2015). The deficiency of Zn and Fe in soils is a worldwide problem. Approximately 50 per cent of wheat-cultivated soil globally is considered poor in bio-available Zn (Cakmak and Kutman, 2018) and about 30 percent of arable cultivated soils across the globe are found deficient in Zn and Fe both. In India, 49 and 15 per cent soils were found deficient in Zn and Fe, respectively (Shukla *etal*.,2012).

Zinc and iron availability have considerable spatial variability in trans-Gangetic plains, and they are in acute shortage In some regions (Shukla *et al*., 2016). Zinc is deficient, and iron is marginal in soils of the arid zone of Haryana (Singh and Banerjee, 1984). Zinc deficiency influences harvest yields, dietary quality, and human well-being. Wheat yield and its quality can be improved by foliar application of Zn and Fe alone or together (Habib, 2009). Soil and foliar application of zinc and iron in wheat impact the Yield contributing characteristics like the productive number of tillers, ear head length,1000-grains weight etc. It also influences quality parameters (Pallavi and Sudha, 2017). Foliar application of iron and zinc increases their concentration in wheat grain as well as in flour (Zhang *et al*., 2010).

Time of spray of micronutrients mostly coincides with the time of application of post-emergence herbicides. Farmers will also be happier to use these concurrently in one go to save time, energy and additional cost. But very less information is available about the compatibility of herbicidal combinations with the zinc and iron sulphate.

MATERIAL AND METHODS

The field experiment was conducted at Choudhary Charan Singh Haryana Agricultural University (CCSHAU), Regional Research Station, Bawal (Rewari) during *Rabi* season of 2018–19. The Soil of the experimental site was alkaline with a pH value of 7.80; low in organic carbon; deficient in available zinc (0.56 ppm) and sufficient in available iron (4.51 ppm). An experiment was laid out in Randomized Block Design (RBD) having 18 treatments, each having 3 replications. Wheat variety WH 1105 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}) and pinoxaden + carfentrazone (50 + 20 gha^{-1}); tank mixed application of above herbicidal combinations with $FeSO_4$ (0.5%); tank mixed application of above herbicidal combinations with ZnSO4 (0.5%) + urea (2.5%); tank mixed application of above herbicidal combinations with $ZnSO_4$(0.5%) + urea (2.5%) + $FeSO_4$(0.5%); rest two were weedy check and weed free. Weed index (WI) was calculated using the following formula:

$$\text{Weed index (\%)} = \frac{(X-Y)}{X} \times 100$$

Where,

X=Yield of crop (wheat) from weed free plot ($Kgha^{-1}$)

Y=Yield of crop (wheat) from treated plot ($Kgha^{-1}$)

Cost of cultivation of the crop (wheat) and 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 following formula:

$$BC\ ratio = \frac{Gross\ returns}{Cost\ of\ cultivation}$$

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 analysed by the online computer programme 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 means of two treatments, the critical difference (C.D.) was worked out by the formula given below:

C.D.=($\sqrt{2xEMS/n}$)×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

Weed Index

Table1. shows the weed index of different herbicidal combinations and their mixtures with zinc or/and iron in wheat. The highest weed index was observed under weedy check (33.83 %). Among herbicidal combinations, clodinafop + metsulfuron (60 gha^{-1}) showed the highest weed index (8.31 %) followed by 6.67 per cent under sulfosulfuron + metsulfuron (32 g ha^{-1}). Application of mesosulfuron + iodosulfuron (14.4gha^{-1}) recorded lowest weed index (5.09%). The same trend continued when herbicides were applied as tank mixed with zincor / and iron. Lowest weed index (-4.09%) was estimated under the influence of mesosulfuron + iodosulfuron (14.4 gha^{-1})+ $ZnSO_4$ (0.5 %) + urea (2.5 %) + $FeSO_4$ (0.5 %) followed by (-3.11 %) pinoxaden + carfentrazone (50 + 20 gha^{-1})+ $ZnSO_4$ (0.5 %) + Urea (2.5 %) + $FeSO_4$ (0.5 %).

The weed index is a measure of the effect of weeds on crop yield, which decreased with the application of herbicidal combinations as compared to the weedy check. The addition of zincor / and iron further increased the weed control and crop yield and resulted in a lower weed index. Mixing of both the micronutrients with herbicidal combinations resulted in crop yield, higher than weed free, which led to negative weed index values. Although there were more weeds in treatments containing herbicidal combinations tank mixed with both micronutrients than the weed free, crop yield was higher. Mesosulfuron + iodosulfuron@14.4 gha^{-1} resulted into maximum control of grassy as well as broad leaf weeds and lowest weed index. Similar results have been reported by Singh (2019) and Pal *et al*. (2016). The addition of micronutrients to herbicides increased weed control efficiency of herbicides. Similar increase in weed control has been reported by Sabeti (2015) where in about 10 percent increase in herbicide efficacy was reported due to tank mixture of micronutrients and herbicides.

Economics

Various treatments affected the economics of weed control in wheat to different extents. The economics of different treatments of present study was calculated and presented in Table 2. Among all herbicidal combinations viz. clodinafop + metsulfuron (60 gha^{-1}), sulfosulfuron + metsulfuron (32 gha^{-1}), mesosulfuron + iodosulfuron (14.4 gha^{-1}) and pinoxaden + carfentrazone (50+20 gha^{-1}), highest gross returns (Rs. 119069 ha^{-1}), net returns (Rs. 50421 ha^{-1}) and benefit cost ratio (1.73) were fetched by application of mesosulfuron + iodosulfuron (14.4 gha^{-1}) followed by sulfosulfuron + metsulfuron (32 gha^{-1}) which fetched net returns (Rs. 49358 ha^{-1}) and benefit cost ratio (1.72). Pinoxaden + carfentrazone (50 + 20 gha^{-1}) accrued highest cost of cultivation (Rs.69373 ha^{-1}), which led to lower net returns and benefit-cost ratio than mesosulfuron + iodosulfuron and sulfosulfuron +

metsulfuron. Minimum gross returns (Rs. 115417 ha^{-1}), net returns (Rs. 47194 ha^{-1}) and benefit-cost ratio (1.69) were brought by the application of clodinafop + metsulfuron (60gha^{-1}). Same trend continued when herbicidal combinations were applied as tank mixed with Zn or/ and Fe. Application of herbicidal combinations mixed with iron {$FeSO_4$ (0.5 %)} increased the cost of cultivation but it also resulted in increase in gross returns of wheat, with respective herbicidal combination which led to increase in net returns as well as benefit cost ratio. Similarly, application of herbicidal combinations mixed with zinc {($ZnSO_4$ (0.5 %) + urea (2.5 %)} further increased cost of cultivation, gross returns, net returns and benefit cost ratio. Combined application of zinc and iron {$ZnSO_4$ (0.5%) + urea (2.5%) + $FeSO_4$ (0.5%)} with herbicidal combinations resulted into more increase in all economic parameters i.e. cost of cultivation, gross returns, net returns and benefit cost ratio than their separate application (either zinc or iron). Among all the treatments highest gross returns (Rs.130173 ha^{-1}), net returns (Rs.60973 ha^{-1}) and benefit cost ratio (1.88) were obtained with-application of mesosulfuron + iodosulfuron (14.4 gha^{-1}) + $ZnSO_4$ (0.5 %) + urea (2.5 %) + $FeSO_4$ (0.5 %). Sulfosulfuron + metsulfuron (32gha^{-1}) + $ZnSO_4$ (0.5%) + urea (2.5%) + $FeSO_4$ (0.5%) was found economically second-best treatment with net returns (Rs. 59731 ha^{-1}) and benefit cost ratio (1.87). Due to higher cost (Rs.69925 ha^{-1}), pinoxaden + carfentrazone (50 + 20 gha^{-1}) + $ZnSO_4$ (0.5 %) + urea (2.5 %) + $FeSO_4$ (0.5 %) could retain the third position in terms of net returns (Rs.59219 ha^{-1}) and benefit cost ratio (1.85) followed by clodinafop + metsulfuron (60 gha^{-1}) + $ZnSO_4$ (0.5 %) + urea (2.5 %) + $FeSO_4$ (0.5 %).

Lowest cost of cultivation (Rs.66773 ha^{-1}), gross returns (Rs.86167 ha^{-1}), net returns (Rs.19394 ha^{-1}) and benefit cost ratio (1.29) were found to be associated with weedy check. In contrast, highest cost of cultivation was associated with weed free (Rs. 85273 ha^{-1}) which reduced its net returns (Rs. 39990 ha^{-1}) and benefit cost ratio to 1.47. Gross returns worked out for weed free was Rs.125263 ha^{-1}. highest cost of cultivation was incurred in maintaining weed free plots due to the high cost of labour.

Gross returns under weed free were higher than other weed control treatments except herbicidal combinations tank mixed with both zinc and iron, However, due to highest cost of cultivation its benefit cost ratio was lower than other treatments. Among herbicidal combinations, the highest cost was associated with pinoxaden + carfentrazone (50 + 20 gha^{-1}) owing to higher cost of herbicide cost (pinoxaden). Highest gross returns, net returns and benefit cost ratio were attained in the treatment of mesosulfuron + iodosulfuron (14.4gha^{-1}). Higher grain and straw yield in this treatment due to effective weed control fetched higher returns. These results conformed the results reported by Kumar *et al*. (2014). A similar increase in net returns and benefit cost ratio due to application of herbicidal combinations was reported by Patel *et al*. (2017). Application of zinc or / and iron with herbicides resulted into higher gross returns (due to higher grain and straw yield) with lesser increase in cost of cultivation (lesser application cost) which led to increase in net returns and benefit cost ratio. Simultaneous application of herbicidal combinations with micronutrients is more economical than their separate application (Fageria*etal*.,2009).

Conclusion

All the herbicidal combinations tested under study lowered the weed index. Tank mixing of micronutrients further lowered the weed index. Any treatment resulting in higher net returns could be evaluated as the best treatment, and in the current study mesosulfuron + iodosulfuron (14.4 gha^{-1}) + $ZnSO_4$ (0.5 %) + urea (2.5 %) + $FeSO_4$ (0.5 %) resulted in 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. It can be concluded that zinc or/and iron sulphate can be used as tank mix with above mentioned herbicidal combinations successfully.

Table 1 Weed index of different weed control treatments in wheat

Treatment	Dose (g ha^{-1})	Weed index (%)
Clodinafop+metsulfuron	60gha^{-1}	8.31
Sulfosulfuron+metsulfuron	32gha^{-1}	6.67
Mesosulfuron+iodosulfuron	14.4gha^{-1}	5.09
Pinoxaden+carfentrazone	50+20gha^{-1}	5.98
Clodinafop+metsulfuron+$ZnSO_4$+urea	60gha^{-1}	3.84
Sulfosulfuron+metsulfuron+$ZnSO_4$+urea	32gha^{-1}	2.31
Mesosulfuron+iodosulfuron+$ZnSO_4$+urea	14.4gha^{-1}	1.01
Pinoxaden+carfentrazone+$ZnSO_4$+urea	50+20gha^{-1}	2.05
Clodinafop+metsulfuron+$FeSO_4$	60gha^{-1}	4.83
Sulfosulfuron+metsulfuron+$FeSO_4$	32gha^{-1}	2.97
Mesosulfuron+iodosulfuron+$FeSO_4$	14.4gha^{-1}	1.85
Pinoxaden+carfentrazone+$FeSO_4$	50+20gha^{-1}	2.71
Clodinafop+metsulfuron+$ZnSO_4$+urea+$FeSO_4$	60gha^{-1}	-0.63
Sulfosulfuron+metsulfuron+$ZnSO_4$+urea+$FeSO_4$	32gha^{-1}	-2.38
Mesosulfuron+iodosulfuron+$ZnSO_4$+urea+$FeSO_4$	14.4gha^{-1}	-4.09
Pinoxaden+carfentrazone+$ZnSO_4$+urea+$FeSO_4$	50+20gha^{-1}	-3.11
Weedy check	--	33.83
Weed free	--	0.00

Table 2 Economics of herbicidal combinations and their tank mixtures with zinc or/and iron sulphate applied in wheat

Treatment	Dose (g ha^{-1})	Cost of Cultivation ha^{-1})	Gross (Rs.Returns ha^{-1})	Net (Rs.Returns ha^{-1})	B:C (Rs.
Clodinafop+metsulfuron	60gha^{-1}	68223	115417	47194	1.69
Sulfosulfuron+metsulfuron	32gha^{-1}	68098	117456	49358	1.72
Mesosulfuron+iodosulfuron	14.4gha^{-1}	68648	119069	50421	1.73
Pinoxaden+carfentrazone	50+20gha^{-1}	69373	118184	48811	1.70
Clodinafop+metsulfuron+$ZnSO_4$+urea	60gha^{-1}	68725	120797	52072	1.76
Sulfosulfuron+metsulfuron+$ZnSO_4$+urea	32gha^{-1}	68600	122538	53938	1.79
Mesosulfuron+iodosulfuron+$ZnSO_4$+urea	14.4gha^{-1}	69150	124021	54871	1.79
Pinoxaden+carfentrazone+$ZnSO_4$+urea	50+20gha^{-1}	69875	122824	52949	1.76
Clodinafop+metsulfuron+$FeSO_4$	60gha^{-1}	68523	119668	51145	1.75
Sulfosulfuron+metsulfuron+$FeSO_4$	32gha^{-1}	68398	121851	53453	1.78
Mesosulfuron+iodosulfuron+$FeSO_4$	14.4gha^{-1}	68948	123009	54061	1.78
Pinoxaden+carfentrazone+$FeSO_4$	50+20gha^{-1}	69673	122148	52475	1.75
Clodinafop+metsulfuron+$ZnSO_4$+urea+$FeSO_4$	60gha^{-1}	68775	126243	57468	1.84
Sulfosulfuron+metsulfuron+$ZnSO_4$+urea+$FeSO_4$	32gha^{-1}	68650	128381	59731	1.87
Mesosulfuron+iodosulfuron+$ZnSO_4$+urea+$FeSO_4$	14.4gha^{-1}	69200	130173	60973	1.88
Pinoxaden+carfentrazone+$ZnSO_4$+urea+$FeSO_4$	50+20gha^{-1}	69925	129144	59219	1.85
Weedy check	--	66773	86167	19394	1.29
Weed free	--	85273	125263	39990	1.47

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