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Effect of weed management practices on weed flora of wheat crop (*Triticum aestivum* L.)

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Abstract
The field experiment was conducted to study the effect of weed management practices on productivity of wheat (*Triticum aestivum* L.) during *rabi* season of 2016-17 at Agronomy Farm of Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (U.P.). Post emergence application of Sulfosulfuron + metsulfuron @ 30+2 g ha^{-1} being at par with hand weeding @ 20 & 40 DAS and Fenoxaprop P-ethyl + Metribuzin @ 100+75 gha^{-1} where significantly reduced the density and dry weight of weeds as compared to other treatments. The post emergence application of Sulfosulfuron + metsulfuron (Total) @ 30+2 g ha^{-1} significantly increased, all the growth and yield contributing characters *viz*., Plant height, leaf area index, dry matter accumulation, length of spike, effective shoots, no. of grains spike^{-1}, test weight, grain, straw and biological yield obtained. Nitrogen and protein content in grain was not affected significantly. Thus Sulfosulfuron + metsulfuron @ 30+2 g ha^{-1} were found higher than the rest of treatments. Sulfosulfuron + metsulfuron @ 30+2 g ha^{-1} was recorded the highest net return of 59641 Rs.ha^{-1} and benefit cost ratio (1.76) followed by Clodinafop + Metsulfuran @ 60+4 g ha^{-1} Rs. ha^{-1} and benefit cost ratio (1.63).
Thus, it is concluded that for effective weed control and higher return of post emergence application of Sulfosulfuron + metsulfuron @ 30+2 g ha^{-1} herbicide applied at 25-30 days after sowing may be adopted in wheat crop.

Keywords: Post emergence, herbicides, weed, wheat

Introduction

Wheat (*Triticum aestivum* L.) is staple food of the world and falls under *poaceae* family. It is primarily grown in temperate regions and also at higher altitude under tropical climatic areas in winter season. Wheat ranks first in the world among the cereals both in respect of area (219.42 million hectare) and production (758.38 million metric tonnes) with productivity of wheat 3.46 t ha^{-1} (FAS/USDA 2017-18) [15]. In India, it is cultivated on an area of 30.79 million hectare having production of 98.51 million metric tonnes with a productivity of 3.20 t ha^{-1} (FAS/USDA 2017-18) [15].

Currently, India ranks second in wheat production in the world next to China in terms of area and production, producing 90-95 million tonnes of wheat from 29-31 million hectare area (Kamboj *et al*., 2017) [5]. Among various factors responsible for low yield, weeds infestation and their management is one of the important factors. Weed competes with crop plants for water, nutrients, space and solar radiation resulting in reduction of yield by 20 to 50% (Bhan, 1998) [2]. Herbicide have shown to be beneficial and very effective means of controlling weeds in wheat because they are quite effective and efficient (Azad *et al.*, 1997) [1]. In economic terms, the value of grassy herbicide portion of the total herbicide market is estimated to be around 70%.

Weeds, the unwanted plants produce large number of seeds which remain dormant in the soil and become alive in favourable climatic conditions and compete with wheat crop for nutrition, water, sun light, space, air and are also fast in growth. The major constraints for wheat are poor crop stand, late planting, poor soil condition due to puddling, imbalance use of fertilizer, problem of weeds specially *Phalaris minor, Avena ludoviciana*, high cost of production due to excess tillage etc. (Pal *et al*. 1996) [7].

The prominent weeds noted in wheat fields are *Phalaris minor, Chenopodium album, Anagallis arvensis, Avena fatua, Convolvulus arvensis, Lathyrus aphaca, Cyperus rotundus* and *Cynodon dactylon* etc. which alone cause 33 per cent reduction in wheat yield. Rice-wheat is one of the most important cropping systems in northern part of the country.

The *Phalaris minor* is one of the very serious problems in wheat in this cropping system and sometimes almost 65 per cent crop losses have been reported, (Chhokar *et al.*, 2008) [4] some broad leaved weeds are also causing a threat but their control is comparatively easier and effective but control of *Phalaris minor* has become a serious challenge. Some of the resistant types of the *Phalaris minor* were reported against isoproturon in 1990s from Haryana and western U.P. and later on some new herbicides molecules eg. Sulfosulfuron, Clodinafop, Isoproturon and fenoxaprop Pethyl were registered and recommended to control the *Phalaris minor* in wheat Walia, U. S and Brar, L. S (2006) [12]. After 2010 these herbicides have also been proved ineffective to control this weed. Likewise, due to the repeated application of grassy weed killer molecules, infestation of broad leaved weeds becoming a serious problem in the wheat fields. Under such circumstances, there is an urgent need to find out some other molecules which may be quite effective against not only to grassy weeds but also take care of broad leaves weed. In the present investigation, some of the new herbicides molecules (combinations) having its very high potency at lower doses to kill grassy along with broad leaved weeds have been developed as ready mixed. These molecules may be proved more effective to control various weed species as well as relatively safer for environmental pollution point of view.

Weed infestation is one of the main causes of low wheat yield not only in India but all over the world, as it reduces wheat yield by 37-50% (Waheed *et al.*, 2009) [11] which may be minimized to a greater extent simply by adopting an appropriate weed management practices. Many methods of weed control are being practiced but no one is absolute. The manual weeding besides expensive and pains taking cannot be practiced until weeds put forth sufficient vegetative growth. Introduction of herbicides has made it possible to control a wide spectrum of weeds in wheat effectively. Herbicide like Sulfosulfuron + Metsulfuron @ 0.096 g ha^{-1} registered highest weed control efficiency of 82.27% (Singh *et al.*, 2017) [10].

Materials and Methods

The field experiment was conducted to study the effect of weed management practices on productivity of wheat (*Triticum aestivum* L.) during *rabi* season of 2016-17 at Agronomy Farm of Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (U.P.). The experiment consisted nine treatments *viz.*, T_1- Sulfosulfuran @ 30 g ha^{-1}, T_2- Clodinafop + Metsulfuran @ 60+4 g ha^{-1}, T_3- Fenoxaprop P-ethyl + Metribuzin (RM) @ 100+75 g ha^{-1}, T_4- Mesosulfuran methyl + Idosulfuran methyl (RM) @ 12+2.4 g ha^{-1}, T_5- Sulfosulfuron + metsulfuron @ 30+2 g ha^{-1}, T_6- Pendimethalin (PE) fb 2,4-D Na @ 1000+500 g ha^{-1}, T_7- Metribuzin @ 175 g ha^{-1}, T_8- Hand weeding @ 20 & 40 DAS T_9-Weedy check. The experiment was conducted in Randomized block design with three replications. The soil of the experimental field was silt loam in texture, low in organic carbon (0.32), nitrogen and medium in available phosphorus and potash having pH 8.0 and EC 0.93 dsm^{-1}. The wheat variety HUW 234 was sown on 07th December, 2016. Nitrogen 120 kg N ha^{-1}, Phosphorus 60 kg P_2O_5 ha^{-1} and Potassium 40 kg K_2O ha^{-1}, were applied through urea, single super phosphate and murate of potash.

Table 1: Physico-chemical properties of the experimental soil

S. No.	Particulars	Values	Methods of analysis
A	**Physical properties**		
1	Sand (%)	28.5	Hydrometer (Bouyoucos, 1962)
2	Silt (%)	54.00	
3	Clay (%)	17.5	
4	Textural class	Silt loam	Triangular method, (Lyon *et al.*, 1952)
S. No.	**Particulars**	**Values**	**Methods of analysis**
B	**Chemical properties**		
1	Soil reaction (pH) (1:2.5 soil water ratio)	8.0	Glass electrode pH meter (Jackson, 1967)
2	Organic carbon (%)	0.32	Walkley & Black's method volumetric (Walkley & Black, 1934)
3	Electrical conductivity 1:2.5 (dSm^{-1})	0.93	Electrical Conductivity bridge meter (Richards, 1954)
4	Available Nitrogen (kg ha^{-1})	180.0	Alkaline permanganate method (Subbiah & Asijah, 1956)
5	Available phosphorus (kg ha^{-1})	18.0	Olsen's method (Olsen *et al.* 1954)
6	Available Potassium (kg ha^{-1})	260.0	Flame photometer method (Jackson, 1954)

Experimental details

The treatments were allocated to different plot at random in all the three replications using the random tables.

Table 2: Details of treatments with their symbols

S. No.	Details of treatments	Symbols
1	Sulfosulfuran @ 30 g ha^{-1}	T_1
2	Clodinafop + Metsulfuran (RM) @ 60+4 g ha^{-1}	T_2
3	Fenoxaprop P-ethyl + Metribuzin (RM) @ 100+75 g ha^{-1}	T_3
4	Mesosulfuran methyl + idosulfuran methyl (RM) @ 12+2.4 g ha^{-1}	T_4
5	Sulfosulfuran + metsulfuron (RM) @ 30+2 g ha^{-1}	T_5
6	Pendimethalin (PE) fb 2,4-D Na (POE) @ 1000+500 g ha^{-1}	T_6
7	Metribuzin @ 175 g ha^{-1}	T_7
8	Hand weeding (20 & 40 DAS)	T_8
9	Weedy check	T_9

Result and Discussion

Weed Flora

The major flora recorded in weedy check was *viz. Phalaris minor* of grassy group, *Chenopodium album, Anagallis arvensis, Melilotus alba, Convonvulus arvensis* were of broad leaf group and *Cyperus rotundus* of sedges group. The other less important weeds were *Cynodon dactylon, Vicia hirsuta, Lathyrus aphaca, Avena fatua.* Similar weed flora of wheat crop under normal sown condition have also reported by Rahaman and Mukherjee, (2009) [8].

Table 3: Weed flora of experimental crop

	Weed species	Common name	Family	Habitat
A- Grasses				
1.	*Phalaris minor*	Canary grass	Poaceae	Annual
2.	*Avena fatua*	Wild oat	Poaceae	Annual
3.	*Cynodon dactylon*	Bermuda grass	Poaceae	Annual
B- Sedges				
1.	*Cyperus rotundus*	Nut sedge	Cyperaceae	Perennial
C- Broad leaf weeds				
1.	*Chenopodium album* L.	Lambs quarter	Chaenopodiaceae	Annual
2.	*Anagallis arvensis* L.	Blue pimpernal	Primulaceae	Annual
3.	*Convonvulus arvensis* L.	Field binder	Convonvulaceae	Annual
4.	*Melilotus alba* Medikus	Sweet clover	Leguminaceae	Annual
5.	*Coronopus spp.*	Lesser swine-cress	Brassicaceae	Annual

Weed Density

Species wise weed density recorded at 30th, 60th, 90th day stages and at harvest stage have been presented in Table-4. that weedy check recorded the highest weed density while the lowest was recorded by Sulfosulfuran + Metsulfuron @ 30+2 g ha^{-1} at all the stages of crop growth. At 30 DAS, before application of herbicide highest density of *Phalaris minor* followed by *Anagallis arvensis.* were recorded. At 60 and 90 days' stages, the density of all the weed species decreased due to various herbicidal treatments. Effective weed control in wheat by the use of sulfosulfuron alone or its combination with other herbicides by Mishra, P.K. and Kewat, M.L.A. (2007) [6]

Table 4: Effect of various weed control treatments on weed density at different growth stages

	Treatments	Weed Density (No. m^{-2}) 30 DAS	60 DAS	90 DAS	At harvest
T_1	Sulfosulfuran @ 30 g ha^{-1}	11.78** (137.9)*	10.92 (118.4)	12.0 (143.2)	7.21 (51.1)
T_2	Clodinafop + Metsulfuran (RM) @ 60+4 g ha^{-1}	11.86 (139.7)	9.20 (83.8)	10.57 (110.9)	5.74 (33.0)
T_3	Fenoxaprop P-ethyl + Metribuzin (RM) @ 100+75 g ha^{-1}	11.89 (140.4)	9.51 (89.5)	10.83 (116.3)	6.15 (36.9)
T_4	Mesosulfuran methyl + idosulfuran methyl (RM) @ 12+2.4 g ha^{-1}	11.98 (142.6)	9.86 (96.2)	11.03 (120.7)	6.32 (40.0)
T_5	Sulfosulfuran + metsulfuron (RM) @ 30+2 g ha^{-1}	11.93 (141.5)	8.35 (68.8)	10.14 (102.0)	5.37 (27.9)
T_6	Pendimethalin (PE) fb 2,4-D Na (POE) @ 1000+500 g ha^{-1}	9.24 (84.5)	10.24 (103.9)	11.36 (128.2)	6.66 (43.4)
T_7	Metribuzin @ 175 g ha^{-1}	11.71 (136.3)	10.80 (115.8)	11.85 (139.6)	7.04 (48.6)
T_8	Hand weeding (20 & 40 DAS)	8.22 (66.7)	9.76 (94.4)	10.41 (107.4)	5.66 (31.1)
T_9	Weedy check	11.95 (141.9)	14.13 (198.8)	14.70 (215.3)	14.29 (203.4)
	S.Em ±	1.75	1.93	1.91	1.23
	CD at 5%	5.25	5.80	5.73	3.83

* The value in parentheses are original value.

** Value transformed by $\sqrt{x+1}$

Among herbicides as post emergence Sulfosulfuron + Metsulfuron @ 30+2 g ha^{-1} has been found most effective to reduce the population of almost all species of weed flora followed by Clodinafop + Metsulfuran 60+4 g ha^{-1} and both the treatments were found significantly better to control weeds of different species as compared to weedy check and other weed control treatments.

Weed dry matter (g m^{-2})

The data presented in the Table-5 and illustrated clearly reveal that weed dry matter was not affected significantly at 30 days stage as the herbicides were applied in pre emergence and post emergence, weed dry matter was recorded at 30, 60, 90 days after sowing and at harvest. The minimum weed dry matter was recorded in Sulfosulfuron + Metsulfuron @ 30+2 g ha^{-1} followed by two hand weeding and Clodinafop + Metsulfuran @ 60+2 g ha^{-1} both the treatments showed significantly lower weed dry matter than rest of the treatments. At harvest, the maximum weed dry matter of 17.38 gm^{-2} was recorded in weedy check control which was significantly higher than all the treatment. Similar findings were also reported by Chippa *et al.* (2005) [3].

Table 5: Effect of weed control treatments on Dry matter accumulation of weed flora at different growth stages

	Treatments	Weed Dry Matter (g m^{-2}) 30 DAS	60 DAS	90 DAS	At harvest
T_1	Sulfosulfuran @ 30 g ha^{-1}	6.31 (38.9)	10.12 (101.50)	11.35 (127.90)	8.42 (69.90)
T_2	Clodinafop + Metsulfuran (RM) @ 60+4 g ha^{-1}	6.44 (44.5)	9.17 (83.10)	10.77 (115.51)	5.20 (26.10)
T_3	Fenoxaprop P-ethyl + Metribuzin (RM) @ 100+75 g ha^{-1}	6.50 (41.3)	9.40 (87.40)	11.10 (122.4)	5.55 (29.90)

T_4	Mesosulfuran methyl + idosulfuran methyl (RM) @ 12+2.4 g ha^{-1}	6.67 (43.5)	9.55 (90.30)	11.38 (128.7)	5.88 (33.60)
T_5	Sulfosulfuran + metsulfuron (RM) @ 30+2 g ha^{-1}	6.20 (37.5)	8.01 (63.20)	9.86 (96.3)	4.58 (20.00)
T_6	Pendimethalin (PE) fb 2,4-D Na (POE) @ 1000+500 g ha^{-1}	5.48 (30.06)	9.69 (92.90)	11.60 (133.6)	6.04 (35.50)
T_7	Metribuzin @ 175 g ha^{-1}	6.38 (39.8)	9.96 (98.40)	11.93 (141.4)	7.94 (62.10)
T_8	Hand weeding (20 & 40 DAS)	5.28 (26.90)	8.08 (64.4)	10.10 (101.2)	4.91 (23.2)
T_9	Weedy check	6.60 (42.60)	17.62 (309.7)	18.57 (344.20)	17.38 (301.10)
S.Em ±		1.21	1.93	0.91	1.01
CD at 5%		3.63	5.80	2.74	3.03

Weed control efficiency

The data presented in Table-6 clearly reveals that the highest W.C.E. was recorded with post emergence application of Sulfosulfuron + metsulfuron @ 30+2 g ha^{-1} (93.35%) closely followed by hand weeding (92.29%) and Clodinaf of + metsulfuran @ 60+4 g ha^{-1} (91.33%) while minimum efficiency was recorded in Sulfosulfuran @ 30 g ha^{-1} (76.78%). This was mainly due to lowest weed dry weight under the effects of above treatment. Chhipa *et al.* (2005) [3], Wallia *et al.* (2011) [13] have also reported increase in weed control efficiency with use of herbicides in wheat.

Weed index: The data presented in Table-6 clearly reveal that the weed index which denotes the percent reduction in grain yield as compare to weed free plot, indicate that infestation of weed reduced the grain yield of wheat by 40.51% and the reduction in grain yield was reduced with control of weeds through herbicides ranging from 5.73% to 19.08%. The minimum reduction in grain yield was noted with hand weeding and post emergence application of Clodinafop + Metsulfuran 60+4 g ha^{-1} closely followed by Fenoxaprop P-ethyl + Idosulfuran methyl @ 100+75 g ha^{-1}. The results are in agreement with Chhipa *et al.* (2005) [3]

Table 6: Effect of various weed control treatments on weed control efficiency and weed index

Treatment		W.C.E. (%)	W.I. (%)
T_1	Sulfosulfuran @ 30 g ha^{-1}	76.78	19.08
T_2	Clodinafop + Metsulfuran (RM) @ 60+4 g ha^{-1}	91.33	5.73
T_3	Fenoxaprop P-ethyl + Metribuzin (RM) @ 100+75 g ha^{-1}	90.06	6.90
T_4	Mesosulfuran methyl + idosulfuran methyl (RM) @ 12+2.4 g ha^{-1}	88.84	8.07
T_5	Sulfosulfuran + metsulfuron (RM) @ 30+2 g ha^{-1}	93.35	0.00
T_6	Pendimethalin (PE) fb 2,4-D Na (POE) @ 1000 + 500 g ha^{-1}	88.20	10.53
T_7	Metribuzin @ 175 g ha^{-1}	79.37	17.44
T_8	Hand weeding (20 & 40 DAS)	92.29	3.39
T_9	Weedy check	0.00	40.51

Economics

The highest cost of cultivation of Rs.38359 ha^{-1} was incurred under hand weeding against the lowest cost of cultivation of Rs.32359 ha^{-1} of weedy check. All the treatments higher gross return, net return and benefit cost ratio over weedy check. The maximum gross income of Rs.93460 ha^{-1} was obtained with Sulfosulfururon + metsulfuron @ 30+2 g ha^{-1} followed by hand weeding (Rs.90159 ha^{-1}) against lowest gross income of Rs.55955 ha^{-1} of weedy check. Sulfosulfururon + metsulfuron @ 30+2 g ha^{-1} recorded the highest net return of Rs.59641 ha^{-1} closely followed by post emergence application of Clodinafop + Metsulfuran @ 60+4 ha^{-1} (Rs.54627 ha^{-1}) and against lowest net return of Rs.23596 ha^{-1} noted with weedy check. Sulfosulfururon + metsulfuron @ 30 + 2 g ha^{-1} as well as Clodinafop + Metsulfuran @ 60+4 g ha^{-1} treatments also recorded highest benefit cost ratio of 1.76, 1.63 as compared to weedy check of 0.72. The results are in agreement with Sharma *et al.* (2015) [9].

Table 7: Effect of various weed control treatments on Economics

Treatments		Grain yield (q ha^{-1})	Total cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B-C ratio
T_1	Sulfosulfuran @ 30 g ha^{-1}	34.55	33759	75284	41525	1.23
T_2	Clodinafop + Metsulfuran (RM) @ 60+4 g ha^{-1}	40.25	33459	88086	54627	1.63
T_3	Fenoxaprop P-ethyl + Metribuzin (RM) @ 100+75 g ha^{-1}	39.75	33479	86834	53355	1.59
T_4	Mesosulfuran methyl + idosulfuran methyl (RM) @ 12+2.4 g ha^{-1}	39.25	34034	85729	51695	1.51
T_5	Sulfosulfuran + metsulfuron (RM) @ 30+2 g ha^{-1}	42.70	33819	93460	59641	1.76
T_6	Pendimethalin (PE) fb 2,4-D Na (POE) @ 1000+500 g ha^{-1}	38.20	33634	83515	49881	1.48
T_7	Metribuzin @ 175 g ha^{-1}	35.25	33134	77069	43935	1.32
T_8	Hand weeding (20 & 40 DAS)	41.25	38359	90159	51800	1.35
T_9	Weedy check	25.40	32359	55955	23596	0.72

Conclusion

The highest grain yield 42.70 qha^{-1} was achieved by application of Sulfosulfuran + metsulfuron (RM) @ 30+2 g ha^{-1} followed by two hand weeding at 20 & 40 days after sowing and lowest yield is found in weedy check. Among the different herbicides application of Sulfosulfuran + metsulfuron @ 30 + 2 gha^{-1} was found most effective to control of all types of weeds followed by two hand weeding. Among different weed control treatments application of sulfosulfuran + metsulfuron @ 30 + 2 g ha^{-1} was most suitable for improving growth, yield and quality of wheat followed by two hand weeding. Sulfosulfuran + metsulfuron @ 30+2 g ha^{-1} was recorded highest net return (Rs 59641 ha^{-1}) and highest B.C Ratio (1.76) followed by Clodinafop + Metsulfuran @ 60+4 g ha^{-1} net return (Rs. 54627 ha^{-1}) and B.C. Ratio (1.63).

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