Indian Journal of Agronomy **63** (4): 462–466 (December 2018)

Research Paper

Chemical weed management in wheat (*Triticum aestivum*) using ready-mix and tank-mix herbicides

AJEET SINGH KUSHWAHA[1], DINDAYAL GUPTA[2] AND LAKHPAT SINGH[3]

Raja Balwant Singh College, Dr Bhim Rao Ambedkar University, Bichpuri, Agra, Uttar Pradesh 283 105

Received : June 2017; Revised accepted : June 2018

ABSTRACT

A field experiment was conducted at the Bichpuri, Agra, Uttar Pradesh during the winter (*rabi)* seasons of 2011–12 and 2012–13, to evaluate the effect of different grass and broad-leaf herbicides as sole and ready-mix application on weed control in wheat (*Triticum aestivum* L.). Ready-mix application of herbicides proved better than their alone application in suppressing weed number and dry weight. Application of sulfosulfuron + metsulfuron (25 + 4 g/ha) resulted in the highest weed-control efficiency (WCE) as well as herbicide efficiency (HEI) and lowest weed index of 94.8%, 2.97 and 3.3 respectively. The highest grain and stover yield of 4.05 and 6.39 t/ha were obtained from weed-free treatment, although this remained statistically at par with sulfosulfuron + metsulfuron (25 + 4 g/ha) and both the treatments resulted in an increase of 34.6 and 30.2% in grain yield as compared to weedy check respectively. The highest net returns (₹43,200/ha) and benefit: cost ratio (2.40) were obtained with ready-mix application sulfosulfuron metsulfuron (25 + 4 g/ha) among the tested herbicide treatments.

Key words: Economics, Growth, Herbicides, Wheat, Yield,

Amongst cereals, wheat is the most important staple foodgrain crop in Indian diet and main source of protein and calories for a large section of population and is usually accorded a premier place among cereal because the vast acreage devoted to its cultivation (Chauhan *et al*., 2014). Generally, weed competes with crop plant for nutrient, moisture and sunlight. Weeds remove plant nutrients more efficiently than crop plants. If weeds left uncontrolled, they can grow taller than crop plant and inhibit the growth, depending on the degree of competition. Weed reduces the crop yield by 10–15% (Kumar and Das, 2008). Anjuman and Bajwa (2010) reported that, selected wheat varieties incurred 60–75% biomass loss due to weed infestation (Tomar and Tomar, 2014). Over the years, efficacy of herbicides has started declining and there is possibility of development of cross resistance, an increase in GR_{50} values of clodinofop and fenoxaprop under continuous of these herbicides (Dhawan *et al*., 2009). To manage the dynamic and complex weed flora in wheat there is need to evaluate different herbicides to have a broad-spactrum weed control (Chopra *et al*., 2015). Weed control under such condition is necessary to take full advantage of other technological advancements in crop production. Herbicidal control, on the other hand will prevent the costly input being eaten up by weeds and thus, saves the management time and cost and will result in increase of yield and profit.

MATERIALS AND METHODS

The field experiment was conducted during the winter (*rabi*) seasons of 2011–12 and 2012–13 at Agricultural Research Farm, Raja Balwant Singh College, Bichpuri, Agra (27° 2' N, 77° 9' E, 163.4 m above mean sea-level), Uttar Pradesh. The experimental soil was sandy loam, containing organic carbon 0.36%, available N 189.2, P_2O_5 29.70 and K_2O 313.0 kg/ha with *p*H 8.5 and electrical conductivity (EC) 1.65 dS/m at 25°C. There were 14 weed-control treatments, viz. metribuzin @ 210 g/ha, clodinafop @ 60 g/ha, pinoxaden @ 40 g/ha, sulfosulfuron @ 25 g/ha, clodinafop + metribuzin @ 60 + 210 g/ha, pinoxaden + metribuzin @ 40 + 210 g/ha, sulfosulfuron + metribuzin @ 25 + 210 g/ha, Accord Plus (fenoxaprop + metribuzin) @ 120 + 210 g/ha, Total (sulfosulfuron + metsulfuron) @ 25 + 4 g/ha, Atlantis (mesosulfuron + iodosulfuron) @ 14.4 g/ha, Vesta (clodinafop + metsulfuron) @ 60 + 4 g/ha, isoproturon + 2, 4-D @ 1,000 + 500 g/ha, weedy check and weed-free. The treatments were tested in ran-

[1]**Corresponding author's Email:** dgupta072@gmail.com

[1]Assistant Professor, [2]M.Sc. Scholar, Department of Agronomy; [3]Tecnical Assistant, Regional Soil Testing Laboratory, Agra, Uttar Pradesh 283 105

domized block design and replicated thrice. The crop was fertilized with 90 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha in all the treatments. Urea, diammonium phosphate (DAP), and muriate of potash (MOP) were used as the source of N, P_2O_5 and K_2O respectively. Nitrogen computed through DAP was deducted from the 90 Kg N and rest N was applied through urea. One-third N and full P and K were applied basal. One-third dose of N was top-dressed in the form of urea after the first irrigation and the remaining N was applied after the second irrigation. Wheat variety 'PBW 550' was sown on 29 November, 2012 and 25 November, 2013 with the seed rate of 100 kg/ha and row spacing of 20 cm apart respectively. Herbicides were sprayed as per treatment 32 days after sowing (DAS) by Knapsack sprayer fitted with flat-fan nozzle using 500 litres water/ha. Observations on weed density were recorded from 0.5 m^2 quadrate at 2 places in the net plot and converted into density/m^2. Data were subjected to transformation to normalize their distribution. Later these samples were dried at 70°C till a constant weight was obtained. The dry-matter was computed in terms of g/m^2. Weedy check plots remained infected with native population of weeds till harvesting. The data on weed density and weed dry weight were subjected to transformation $\sqrt{X+0.5}$ before statistical analysis. Grain yield recorded in kg/plot was converted into grain yield in kg/ha. The economics was worked out, based on pooled yield data and considering price of input and output of the prevailing market rate. All data were put to analysis of variance as described by Gomez and Gomez (1984). The mean assessment was accomplished by least significant difference (LSD) at 5% level of significance. Weed-control efficiency (WCE), weed index (WI) and herbicide efficiency index (HEI) were calculated as:

$$WCE (\%) = \frac{DWC - DWT}{DWC} \times 100$$

where, DWC, total density of weeds in unweeded control plot and DWT, total density of weeds in treated plot.

$$WI (\%) = \frac{X-Y}{X} \times 100$$

where, X, yield from weed free and Y, yield from particular treatment

$$HEI = \frac{\frac{Y_t - Y_c}{Y_c} \times 100}{\frac{DMT}{DMC} \times 100}$$

where, Y_t, yield from treated plot; Y_c, yield from unweeded control plot; DMT, dry-matter of weeds in treated plot; DMC, dry matter of weeds from unweeded control plot.

RESULTS AND DISCUSSION

Weed dynamics

The major weed species appeared in experimental field were *Chenopodium album*, *Anagallis arvensis, Melilotus alba* and *Convolvulus arvensis* among broad-leaf weeds; and *Phalaris minor* and *Cynodon dactylon* among grasses. Moreover, among sedges, only 1 species, viz. *Cyperus rotundus,* was observed. Weed-management practices significantly reduced the weed population and their dry weight than weedy check. In case of weed population and their dry weight, the lowest values were recorded from weed-free treatment. Ready-mix formulation of sulfosulfuron + metsulfuron (25 + 4 g/ha) proved the most effective herbicidal combination against grassy, broad-leaf and total weeds and recorded significantly lower density of weeds (Table 1). This may be reason for excellent control of total weeds population owing to sequential weed free and differential selectivity towards grassy and broad-leaf weeds with the application of sulfosulfuron + metsulfuron (25 + 4 g/ha). The results are in the agreement with the findings of Chopra *et al*. (2013) and Kaur *et al.* (2015). Ready-mix application of sulfosulfuron + metsulfuron (25 + 4 g/ha) significantly reduced the dry matter of grassy and broad leaved as well as total weeds over all other sole and tankmix application of different herbicides. With chemical and weed-free treatments, the weed population was very much suppressed and hence the production of fresh weight and dry weight were considerably lower. Our results confirm the fundings of Jain *et al.* (2014) and Khan *et al*. (2017). The highest weed-control efficiency of 92.0% was registered with sulfosulfuron + metsulfuron (25 + 4 g/ha), might be owing to lower weed density and dry-matter production of weed which resulted successful checking of weed growth under this treatment. Ready-mix application of sulfosulfuron + metsulfuron (25 + 4 g/ha) resulted in the lowest weed index and the highest herbicide efficiency index, followed by clodinafop + metribuzin (60 + 210 g/ha).

Growth and yield-attributing parameters

Variations in growth and yield-attributes, viz. shoots (no./m), plant height (cm), dry-matter accumulation (g), effective shoots (no./m), spike length (cm), grains/spike, grains weight/spike and test weight owing to different herbicides were significant over weedy check (Table 2). Amongst the herbicidal treatments, the tallest plant, maximum number of shoots/m row length and dry-matter accumulation were recorded in ready-mix application of sulfosulfuron + metsulfuron (25 + 4 g/ha), although this remained statistically at par with some of the herbicidal treatments, namely clodinafop + metribuzinm (60 + 210 g/ha), sulfosulfuron + metribuzin (25 + 210 g/ha), fenoxaprop + metribuzin (120 + 210 g/ha) and mesosulfuron + iodosulfuron (12+2.4 g/ha). This might be owing to better performance of both combined application of herbicides in controlling grassy and broad-leaf weeds and therefore resulted in less weed-crop competition as compared to their alone application. These results are in close conformity with those reported by Pal *et al*. (2016). Weed-free and ready-mix application of sulfosulfuron +

Table 1. Weed density, weed dry matter, weed-control efficiency, weed index and herbicide-efficiency index in wheat as affected by herbicides (mean data of 2 years)

Treatment	Weed density (number/m² at 60 DAS)			Weed biomass (g/m² at 60 DAS)			Weed-control efficiency (%)	Weed index	Herbicide-efficiency index
	Grassy weeds	Broad-leaf weeds	Total weeds	Grassy weeds	Broad-leaf weeds	Total weeds			
Metribuzin 210 g/ha	20	26	6.82 (46)	21.9	41.4	7.98 (63.3)	73.6	16.9	0.23
Clodinafop 60 g/ha	22	29	7.17 (51)	22.3	42.2	8.07 (64.5)	70.7	17.8	0.21
Pinoxaden 40 g/ha	23	30	7.32 (53)	23.2	42.5	8.14 (65.7)	69.5	18.1	0.19
Sulfosulfuron 25 g/ha	19	24	6.58 (43)	21.4	40.9	7.93 (62.3)	75.3	16.1	0.26
Clodinafop + metribuzin 60 + 210 g/ha	8	6	3.77 (14)	08.9	11.3	4.52 (20.2)	92.0	11.3	1.20
Pinoxaden + metribuzin 40 + 210 g/ha	15	13	5.33 (28)	18.5	28.9	6.93 (47.4)	83.9	14.1	0.41
Sulfosulfuron + metribuzin 25 + 210 g/ha	13	10	4.82 (23)	15.8	21.6	6.14 (37.4)	86.8	13.1	0.56
Accord Plus (fenoxaprop + metribuzin) 120 + 210 g/ha	14	11	5.02 (25)	17.2	23.7	6.43 (40.9)	85.6	13.5	0.50
Total (sulfosulfuron + metsulfuron) 25 + 4 g/ha	5	4	3.01 (09)	05.5	07.1	3.59 (12.6)	94.8	03.3	2.97
Atlantis (mesosulfuron + iodosulfuron) 12 + 2.4 g/ha	9	8	4.14 (17)	10.7	15.0	5.10 (25.7)	90.2	11.9	0.89
Vesta (clodinafop + metsulfuron) 60 + 4 g/ha	11	9	4.51 (20)	13.1	20.2	5.81 (33.3)	88.5	12.9	0.65
Isoproturon + 2, 4-D 1,000 + 500 g/ha	18	16	5.86 (34)	20.3	35.2	7.48 (55.5)	80.5	14.8	0.33
Weedy check	95	79	13.24 (174)	51.4	73.9	11.23 (125.3)	0	25.7	0
Weed free	0	0	1.00 (0)	0	0	1.00 (0)	100.0	0	0
SEm±	1.00	0.60	0.24 (2.25)	1.02	0.83	0.21 (1.67)	0.8	-	-
CD (P=0.05)	2.90	1.81	0.71 (6.54)	2.98	2.42	0.60 (4.83)	2.4	-	-

Original figures in parentheses were subjected to square-root transformation $\sqrt{x+0.5}$ before statistical analysis; DAS, days after sowing

Table 2. Effect of herbicides on growth and yield-contributing characters of wheat (mean data of 2 years)

Treatment	Shoots /m row length	Plant height (cm)	Dry-matter accumulation (g)	Effective shoots/m row length	Spike length (cm)	Grains/ spike	Grains weight/ spike	1,000-grains weight (g)
Metribuzin 210 g/ha	72.6	80.4	92.4	67.5	6.01	31.6	2.72	35.6
Clodinafop 60 g/ha	71.7	80.0	91.8	66.8	5.97	31.2	2.68	35.4
Pinoxaden 40 g/ha	70.0	79.6	91.5	65.3	5.85	30.9	2.65	35.1
Sulfosulfuron 25 g/ha	74.5	80.7	92.7	67.8	6.05	31.8	2.76	35.7
Clodinafop + metribuzin 60 + 210 g/ha	79.2	83.8	95.6	72.7	7.05	33.7	3.15	37.9
Pinoxaden + metribuzin 40 + 210 g/ha	75.9	81.8	93.3	68.9	6.23	32.5	2.85	36.1
Sulfosulfuron + metribuzin 25 + 210 g/ha	76.5	82.7	94.2	70.7	6.64	33.0	2.98	36.9
Accord Plus (fenoxaprop + metribuzin) 120 + 210 g/ha	76.1	82.4	93.8	70.1	6.48	32.8	2.91	36.4
Total (sulfosulfuron + metsulfuron) 25 + 4 g/ha	80.0	84.4	96.0	73.4	7.20	34.1	3.20	38.0
Atlantis (mesosulfuron + iodosulfuron) 12 + 2.4 g/ha	78.5	83.5	94.9	71.9	6.90	33.5	3.08	37.5
Vesta (clodinafop + metsulfuron) 60 + 4 g/ha	76.9	83.2	94.5	71.4	6.81	33.2	3.01	37.1
Isoproturon + 2, 4-D 1,000 + 500 g/ha	75.3	81.4	93.0	68.5	6.18	32.2	2.81	36.0
Weedy check	63.7	75.5	86.7	63.1	5.78	29.8	2.58	34.7
Weed-free	84.8	88.3	97.2	75.3	7.80	35.2	3.35	38.5
SEm±	1.29	0.62	0.65	1.42	0.41	0.95	0.14	0.76
CD (P=0.05)	3.75	1.81	1.89	4.11	1.22	2.76	0.42	2.21

metsulfuron (25 + 4 g/ha) treatments recorded significantly effective shoots over weedy check, sole application of metribuzin, clodinafop, pinoxaden, sulfosulfuron and ready-mix application of pinoxaden + metribuzin (40 + 210 g/ha) and Isoproturon + 2, 4-D (1,000 + 500 g/ha). Sulfosulfuron + metsulfuron (25 + 4 g/ha), being at par with all ready-mix application of herbicides, recorded the significantly higher spike length and grains/spike over clodinafop (60 g/ha) and pinoxaden (40 g/ha). The maximum grains weight/spike and 1,000-grains weight recorded with weed free treatment which was comparable with sulfosulfuron + metsulfuron (25 + 4 g/ha) and sulfosulfuron + metribuzin (25 + 210 g/ha) and both the ready-mix formulation were significantly superior to all sole application of different herbicides. The crop remained in advantage with both the treatments and it completed its vegetative growth and development satisfactorily owing to favourable temperature condition which ultimately accumulated more dry matter and promoted the yield attributes favourably. Similar results were also obtained by Mehmood *et al.* (2014).

Yield

Means data showed that the weed-control treatments had significant influence on biological, grain, and straw yields (Table 3). The highest grain and stover yields of 4.05 and 6.39 t/ha were obtained from weed-free treatment, although this remained statistically at par with sulfosulfuron + metsulfuron (25 + 4 g/ha) and both the treatments resulted in an increase of 34.6 and 30.2%, respectively in grain yield as compared to weedy check. It is all because of the fact that both the treatments showed its superiority in most of the yield attributes as well as these results might be because difference in weed dry weight obtained due to weed-control treatments, which resulted in reduced crop weed competition for space, solar radiation interceptions, moisture and nutrient uptake. The results confirmity the findings of Bajya *et al*. (2015) and Pal *et al*. (2016). The weed-free treatment resulted in significantly superior biological yield followed by sulfosulfuron + metsulfuron (25+4 g/ha) as compare to all the other herbicidal treatments. The ready-mix application of 3 combinations, viz. clodinafop + metribuzin (60 + 210 g/ha), mesosulfuron + iodosulfuron (12 + 2.4 g/ha) and clodinafop + metsulfuron (60 + 4 g/ha) remained at par with each other and significantly better than alone application of clodinafop (60 g/ha) and pinoxaden (40 g/ha). It is obvious that dry matter is a net saving of photosynthesis and essential for the building up of plant organs, which ultimately reflect on biomass production. Similar results were found by Meena and Singh (2013), Tomar and Tomar (2014) and Singh *et al*. (2015).

Economics

The weed free and all the herbicides sole or in tank-mix application recorded higher monetary returns than weedy check (Table 3). Among the weed-control treatments, the highest net returns of ₹44,600/ha were obtained from weed-free treatment, followed by sulfosulfuron + metsulfuron (25 + 4 g/ha) and clodinafop + metribuzin (60+210 g/ha). Alone application of herbicides also accured higher net returns/ha than weedy check.

Table 3. Effect of herbicides on yield and economics of wheat (mean data of 2 years)

Treatment	Grain yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Cost of cultivation ($\times10^3$/ha)	Gross returns ($\times10^3$/ha)	Net returns ($\times10^3$/ha)	Benefit: cost ratio
Metribuzin 210 g/ha	3.36	5.01	8.37	30.1	63.0	32.8	2.09
Clodinafop 60 g/ha	3.33	4.95	8.28	30.3	62.3	31.9	2.05
Pinoxaden 40 g/ha	3.31	4.90	8.21	30.8	61.9	31.1	2.01
Sulfosulfuron 25 g/ha	3.40	5.09	8.49	30.4	63.7	33.3	2.09
Clodinafop + metribuzin 60 + 210 g/ha	3.59	5.49	9.08	30.7	67.7	37.0	2.21
Pinoxaden + metribuzin 40 + 210 g/ha	3.48	5.24	8.72	31.2	65.3	34.1	2.09
Sulfosulfuron + metribuzin 25 + 210 g/ha	3.51	5.34	8.85	30.8	66.1	35.4	2.15
Accord Plus (fenoxaprop + metribuzin) 120 + 210 g/ha	3.50	5.28	8.78	31.5	65.7	34.2	2.09
Total (sulfosulfuron + metsulfuron) 25 + 4 g/ha	3.91	6.03	9.94	30.7	73.9	43.2	2.40
Atlantis (mesosulfuron + iodosulfuron) 12 + 2.4 g/ha	3.56	5.45	9.01	31.4	67.2	35.8	2.14
Vesta (clodinafop + metsulfuron) 60 + 4 g/ha	3.53	5.35	8.88	31.6	66.3	34.8	2.10
Isoproturon + 2, 4-D 1,000 + 500 g/ha	3.45	5.20	8.65	31.0	64.8	33.8	2.09
Weedy check	3.01	4.50	7.51	29.4	56.9	27.6	1.94
Weed-free	4.05	6.39	10.44	32.4	77.0	44.6	2.38
SEm±	0.11	0.13	0.12	–	–	–	–
CD (P=0.05)	0.31	0.39	0.36	–	–	–	–

The maximum benefit: cost ratio of 2.40 was recorded with ready-mix application of sulfosulfuron + metsulfuron (25 + 4 g/ha) against 2.38 benefit: cost ratio of weed-free. The profitability was lower under weedy check due to disproportionate decrease in yield on account of higher crop-weed competition. The results confirm the findings of Jain *et al*. (2014) and Chopra *et al*. (2015).

It was concluded that metribuzin and sulfosulfuron were compatible with clodinafop and metsulfuron and there was no adverse effect on efficacy of both the herbicides against the complex weed flora in wheat. Sulfosulfuron + metsulfuron and clodinafop + metribuzin were the most remunerative and effective herbicidal mixture in controlling the weed flora in wheat for achieving the maximum weed-control efficiency and herbicide efficiency index and grain yield.

REFERENCES

Anjuman, T. and Bajwa, R. 2010. Competition losses caused by *Rumex dentatus* L. and *Chenopodium album* L. in wheat (*Triticum aestivum* L.). *The Philippine Agricultural Scientist* **93**(3): 110–115.

Bajya, D.R., Parveen, T., Lakharam, M.C. and Raja, S.K. 2015. Efficacy of new formulations of trisulfuron on weeds in wheat and their residual effects on succeeding maize. *Indian Journal of Agronomy* **60**(1): 57–60.

Chauhan, T.M., Ali, J., Singh, H., Singh, N. and Singh, S.P. 2014. Effect of zinc and magnesium nutrition on yield, quality and removal of nutrients in wheat (*Triticum aestivum* L.). *Indian Journal of Agronomy* **59**(2): 276–280.

Chopra, N.K., Chopra, N. and Choudhary, D. 2015. Bioefficacy of sole and tankmix of pinoxaden and clodinofop with carfentazone and metsulfuron for control of complex weed flora in wheat. *Indian Journal of Agronomy* **60**(1): 104–108.

Dhawan, R., Punia S.S., Singh, S., Yadav, D. and Malik, R.K. 2009. Productivity of wheat as affected by continuous use of new low dose herbicides for management of little canary grass (*Phalaris minor*). *Indian Journal of Agronomy* **54**(1): 58–62.

Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research*, edn 2, John Willey & Sons, Inc., New York, the USA.

Jain, V., Jain, N. and Kewat, M.L. 2014. Effect of application of post-emergence herbicides at different levels of available soil moisture content in irrigated wheat. *Indian Journal of Agronomy* **59**(1): 91–95.

Kaur, T., Bhullar, M.S. and Walia, U.S. 2015. Bio-efficacy of ready mix formulation of clodinafop-propargyl + metsulfuron for control of mixed weed flora in wheat. *Indian Journal of Weed Science* **47**(2): 121–124.

Khan, N., Chaudhry, S., Siddiqui, M.Z., Yadav, R.A. and Husain, K. 2017. Effect of weed management options and nitrogen scheduling on weed dynamics and yield of wheat (*Triticum aestivum* L.) under central plain zone of Uttar Pradesh. *Indian Journal of Agronomy* **62**(4): 464–469.

Kumar, M. and Das, T.K. 2008. Integrated weed management for system productivity and economics in soybean–wheat system. *Indian Journal of Agronomy* **53**(3): 189–194.

Meena, B.L. and Singh, R.K. 2013. Response of wheat to rice and weed management practices. *Indian Journal of Agronomy* **58**(4): 521–524.

Mehmood, Zia, Ashiq, Muhammad, Noorka, Ijaz Rasool, Ali, Amjed, Tabasum, Saba and Iqbal, Muhammad Shahid. 2014. Chemical control of monocot weeds in wheat (*Triticum aestivum* L.). *American Journal of Plant Sciences* **5**(9): 5 pages DOI:10.4236/ajps.59140.

Pal, S., Sharma, R., Sharma, H.B. and Singh, R. 2016. Influence of different herbicides on weed control, nutrient removal and yield of wheat (*Triticum aestivum* L.). *Indian Journal of Agronomy* **61**(1): 59–63.

Tomar, S.K. and Tomar, T.S. 2014. Effect of herbicides and their tank mixture on weed dynamics and yield of zero-tilled wheat (*Triticum aestivum* L.) under rice (*Oriza sativa* L.)–wheat cropping system of eastern Uttar Pradesh. *Indian Journal of Agronomy* **59**(4): 624–628.

Singh, A.P., Pandagare, T., Abrahum, S., Chandrakar, D. and Chowdhury, T. 2015. Evaluation of metribuzin in combination with clodinafop, sulfosulfuron and Pinoxaden for weed control in wheat. *International Journal of Life Science* **10**(1): 271–274.