Indian Journal of Agronomy **59** (4): 624–628 (December 2014)

Research Paper

Effect of herbicides and their tank mixture on weed dynamics and yield of zero-tilled wheat (*Triticum aestivum*) under rice (*Oryza sativa)*–wheat cropping system of eastern Uttar Pradesh

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Received : May 2014; Revised accepted : November 2014

ABSTRACT

An on-farm trial was conducted at Gorakhpur, Uttar Pradesh during the winter seasons of 2010–11 and 2011–12, to assess the efficacy of sulfosulfuron, Clodinofop, metribuzin, mesosulfuran + idosulfuron and tank mixture of sulfosulfuron with 2,4-D, metsulfuron and carfentrazone ethyle as well as clodinofop with metsulfuron in zero-tilled wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] crop. All herbicidal treatments reduced the weed density and weed dry weight significantly compared to weedy check. In general, tank-mix application of herbicides proved better than their alone application in suppressing weed number and dry weight. Highest grain yield (5.17 t/ha) and straw yield (5.79 t/ha) were recorded in weed-free plot, which was at par with clodinofop + metsulfuron (60+2.5 g a.i./ha). Uncontrolled growth of weeds caused 45.3% reduction in the crop yield compared to weed-free treatment. Tank-mix application of clodinofop with metsulfuron and sulfosulfuron with metsulfuron, carfentrazone ethyl and 2, 4-D proved better, showing an increase in grain yield of 14.7% than their alone application. Tank mix application of clodinofop with metsulfuron remaining at par with sulfosulfuron + carfentrazone ethyl significantly reduced the weed density and weed dry weight compared to rest of the herbicides tested. Tank-mix application of clodinofop + metsulfuron remaining at par with sulfosulfuron mix with either carfentrazone ethyl, metsulfuron or 2, 4-D was most effective in enhancing yield attributes, grain and straw yield. Highest net returns (₹33,660/ha) and benefit: cost ratio (2.91) were also obtained using clodinofop + metsulfuron. Application of metribuzin in spite of better weed-control efficiency recorded the lowest grain yield amongst the herbicides tested which was at par with mesosulfuron + idosulfuron.

Key words : Crop protection, Economics, Herbicide, Weed control, Wheat, Yield

Wheat is an important prime cereal crop among the foodgrain and is grown in 27.2 million ha in India, with a average productivity 2.9 tonnes/ha DAC(2012) . The productivity of wheat has increased tremendously in Indo-Gangetic plains but still below from its potential, i.e. 11.2 tonnes/ha (Singh *et al.,* 2010). Among the several causes of low productivity in eastern Uttar Pradesh, increasing population of canary grass (*Phalaris minor* Retz.) with broad leaf weeds causing substantial yield loss in rice–wheat cropping system. Yield reduction due to weeds is 38–42% (Bharat and Kachroo, 2007) or even more. Anjuman and Bajwa (2010) reported that selected wheat varieties incurred 60–75% biomass loss due to weed infestation. With the introduction of high-yielding dwarf varieties having heavy demand of inputs, the problem of weed infestation has increased manifold, as it created favourable condition for invasion as well as luxuriant growth of weeds, particularly *Phalaris minor.* Weeds infestation in wheat is rampant and caused depletion of 31 kg N, 16 kg P and 29 kg k/ha from wheat crop field (Pandey *et al.*, 2007) and considerable amount of secondary and micronutrients, thereby resulting in heavy yield reduction. Commonly used herbicides isoproturon and sulfosulfuron control grassy weeds only but had little effect on troublesome broad-leaf weeds. Further, continuous use of isoproturon caused development of resistant biotypes of *Phalaris minor* (Malik and Singh, 1995). To overcome these problem farmers are applying more nutrients and different brands of herbicides alone or in combination to eliminate the weeds, but such practices lack proper scientific evidences. Hence it is essential to identify alternate herbicide mol-

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ecules with broad-spectrum activity or their combination of available herbicides for sustainable weed management in wheat. Keeping these facts in view, the present investigation was undertaken to study the effect of herbicides alone or in combination on weeds dynamics and yield of zero-till wheat in rice–wheat cropping system in calcareous soils of eastern Uttar Pradesh.

MATERIALS AND METHODS

An on-farm trial in farmer's participatory mode was carried out during the winter season of 2010–11 and 2011–12 at 5 cooperate farmer's field of 5 villages of Gorakhpur district of north eastern plains zone in irrigated ecosystem. All the farmers selected for an-on farm trials were medium in category and early adopter of the technology. Soil sample from all the 5 farmers fields were collected and analysed. The soil of the sites were sandy loam to clay loam with pH 6.5 to 8.2, 0.27 to 0.4% organic carbon, having available nitrogen 210.4 to 272.3 kg/ha, available phosphorus 13.7 to 18.2 kg/ha and available potassium 220.5 to 240 kg/ha. The experiment comprised 10 treatments, viz. sulfosulfuron @ 25 g ai/ha, clodinofop 200 g ai/ha, metribuzin 200 g ai/ha, mesosulfuron + idosulfuron 10 + 2.4 g ai/ha, sulfosulfuron + 2, 4-D @ 25 + 400 g ai/ha, sulfosulfuron + metsulfuron @ 25 + 2.5 g ai/ha, clodinofop + metsulfuron @ 60 + 2.5 g ai/ha, sulfosulfuron + carfentrazone ethyl @ 25 + 20 g ai/ha, weed-free and weedy check, were tested at each farmers field having a plot size of 450 m^2. Wheat 'HD 2733' was sown during mid-November after harvesting of rice adopting zero-tillage technique with the help of zero-tillage machine using 100 kg seed/ha in both the years. The crop was fertilized with recommended dose of fertilizers, viz. 150, 60, 60 kg N, P_2O_5 and K_2O /ha. Whole quantity of P and half of N were applied basal through zero-till machine and the remaining N and K were applied in 2 equal splits at first and second irrigation. The crop was irrigated 3 times at crown-root initiation, before flowering and at milking stage as common practice of eastern Uttar Pradesh. Herbicides were applied as post-emergence (30 DAS) with knap-sack sprayer fitted with flat-fan nozzle using 450 litres water/ha. Weed population (m^2) and weed dry weight (g/m^2) were recorded at 60 days after sowing (DAS) by placing a quadrate of (1 m × 1 m) randomly at 2 places from each plot. The crop was manually harvested in the first week of April during both the years. Yield attributes were recorded before harvesting from each plot. Grain and straw yields were recorded after threshing of the whole plot under each treatment. All the data were analysed statistically by considering 5 farmers as 5 replications in randomized block design. Economics were computed using the prevailing market price of input and output. The data on weed count and dry matter was transformed to square root "X + 0.5 and then analyzed statistically.

RESULTS AND DISCUSSION

Effect on weeds

The weed flora observed in weedy check plot at 60 days after sowing (DAS) were *Phalaris minor* 47.4%, *Avena ludoviciana* Dur. 7.8%, *Chenopodium album* L. 23.8%, *Solanum nigrum* 10.7% and *Fumaria parviflora* Lam. 10.3%. All the herbicides reduced weed population significantly compared to weedy check (Table 1). However, the response of these herbicides on density of individual weed species at 60 DAS revealed that the application of clodinofop (60 g a.i./ha) alone or in combination with metsulfuron showed effective control of grassy weeds *Phalaris minor* and *Avena ludoviciana,* which was significantly superior to mesosulfuron + idosulfuron but

Table 1. Density of different weeds (m^2) as influenced by different herbicides at 60 days after sowing (mean of 2 years data)

Treatment	Dose (g a.i./ha)	*Phalaris minor*	*Avena ludoviciana*	*Chenopodium album*	*Solanum nigrum*	*Fumaria parviflora*
Sulfosulfuron	25	2.00(8.00)	1.74(2.550	4.41(18.99)	3.52(7.41)	2.14(4.12)
Clodinofop	60	1.64(2.17)	1.25(1.07)	4.67(21.32)	3.13(9.30)	3.08(8.99)
Metribuzin	200	2.69(6.75)	2.37(5.15)	1.77(2.65)	1.88(3.05)	1.71(2.43)
Mesosulfuron+ Idosulfuron	10 + 2.4	2.84(7.58)	1.68(2.34)	4.55(20.21)	2.96(8.24)	3.08(9.02)
Sulfosulfuron + 2,4-D	25 +400	1.81(2.78)	2.02(3.60)	1.75(2.55)	2.38(5.19)	1.70(2.41)
Sulfosulfuron + Metsulfuron	25 +2.5	1.87(3.02)	2.01(3.58)	1.84(3.39)	2.59(6.23)	1.76(2.62)
Clodinofop + Metsulfuron	60 +2.5	1.71(2.41)	1.24(1.05)	2.85(3.15)	1.89(3.09)	1.22(1.00)
Sulfosulfuron + Carfentrazone ethyle	25 +20	1.76(2.61)	1.58(1.86)	2.07(3.80)	2.04(3.66)	1.62(2.14)
Weed free		0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
Weedy check		6.10(36.74)	2.56(6.08)	4.29(18.44)	2.96(8.28)	2.91(7.97)
SEm±		0.15	0.20	0.19	0.25	0.20
CD (P=0.05)		0.45	0.60	0.58	0.75	0.61

Figures in parentheses indicate

was at par with rest of the herbicides alone or in combination. The application of sulfosulfuron, clodinofop and mesosulfuron + idosulfuron did not provide any control of the broad leaf weeds in respect of density and weed dry weight. This may be due to narrow spectrum of controlling of the weeds of these herbicides.

Weed-control measures had significant effect on weed population and its dry matter accumulation at 60 DAS (Table 2). All the herbicidal treatment reduced the weed population and dry matter of weeds significantly than the weedy check and thus ultimately enhanced weed-control efficiency. Among the herbicides, tank-mixture application of clodinofop + metsulfuron (60 + 2.5 g a.i./ha) significantly reduced the weed population and dry weight of weeds compared with the other treatments because less weed competition with crop resulted higher grain yield. The results confirm the findings of Singh (2013). Tank-mix application of sulfosulfuron + carfentrazone ethyl (25 + 20 g a.i./ha) and sulfosulfuron + 2, 4-D (25 + 400 g a.i./ha) as well as Sulfosulfuron + metsulfuron (25 + 2.5 g a.i./ha) and sulfosulfuron + 2,4-D (25 + 400 g a.i./ha) remained at par, recording significantly less weed population and dry-matter compared their alone application. This may be because of tank-mixture of these herbicides might have acted synergistically in broadening the spectrum of weed control. These results are in close conformity with the findings of Singh (2013). Highest weed-control efficiency of 89.5% and lowest weed index (3.4) were registered with tank-mix application of clodinofop + metsulfuron (60 + 2.5 g a.i./ha) followed by sulfosulfuron + carfentrazone ethyl (60 + 20 a.i./ha), sulfosulfuron + 2, 4-D (25 + 400 g a.i./ha) and sulfosulfuron + metsulfuron (25 + 2.5 g a.i./ha) owing to effective control of complex weed flora. Meena and Singh (2013) also recorded higher weed-control efficiency with tank-mix application of herbicides over their alone application. Lowest weed control efficiency and higher weed index were recorded with mesosulfuron + idosulfuron due to more weed growth and poor grain yield in the treatment. Owing to persistence of high moisture in the field after application of herbicide resulted poor weed control. The highest weed index was recorded with application of metribuzin (200 g a.i./ha) due to its phytotoxic effect on crop resulting less no of effective tillers/m^2, lowest grains/ear vis-à-vis lowest grain yield among the herbicidal treatments. Sharma (2003) and Bharat and Kachroo (2007) also reported phytotoxic effect of metribuzin on wheat.

Yield and its attributes

The highest number of fertile tillers was recorded with weed-free treatment which was comparable with clodinofop + metsulfuron (60 +2.5 g ai/ha) and sulfosulfuron + metsulfuron (25 + 2.5 g a.i./ha) and significantly superior to rest of the treatments except sulfosulfuron + 2, 4-D (25 + 400 g a.i./ha) which was at par with Sulfosulfuron + metsulfuron (25 + 2.5 g a.i./ha) and sulfosulfuron + carfentrazone ethyl (25 + 20 g a.i./ha). Significantly highest grains/ear and test weight were recorded with weed-free, which was at par with, clodinofop + metsulfuron (60 + 2.5 g a.i./ha), sulfosulfuron + 2, 4-D and sulfosulfuron + metsulfuron and all these recorded significantly higher number of grain and test weight over their alone application. This may be attributed to better weed control with application of tank-mix herbicides than its alone application (Bharat and Kachroo, 2007). All the weed-control treatments significantly improved the grain and straw yields compared to weedy check (Table 3). Highest grain yield of 5.17 t/ha was recorded with weed-free, which was at par with clodinofop + metsulfuron (60 + 2.5 g a.i./ha) but significantly higher with rest of the

Table 2. Effect of herbicide on weed population, weed dry weight and weed control efficiency at 60 days after sowing and weed index (mean data of 2 years)

Treatment	Dose (g a.i./ha)	Weed population (No./m^2)	Weed dry weight(g/m^2)	Weed-control efficiency(%)	Weed index
Sulfosulfuron	25	6.13 (37.10)	6.74 (45.00)	62.2	16.9
Clodinofop	60	6.58 (42.87)	6.77 (45.44)	61.8	16.6
Metribuzin	200	4.53 (20.03)	5.09 (25.47)	78.6	23.7
Mesosulfuron Idosulfuron	10 + 2.4	7.14 (50.52)	7.52 (56.16)	60.9	18.3
Sulfosulfuron + 2, 4-D	25 +400	4.13 (16.53)	4.20 (17.20)	85.5	8.1
Sulfosulfuron + Metsulfuron	25 +2.5	4.47 (19.45)	4.26 (17.72)	85.1	6.6
Clodinofop + Metsulfuron	60 +2.5	3.35 (10.70)	3.52 (12.46)	89.5	3.4
Sulfosulfuron + Carfentrazone ethyle	25 +20	3.82 (14.10)	3.95 (15.11)	87.2	9.6
Weed free		0.71 (0.00)	0.71 (0.00)	100	-
Weedy check		8.83 (77.51)	10.90 (118.70)	-	45.3
SEm±		0.15	0.20	-	-
CD (P=0.05)		0.45	0.60	-	-

treatments. The tank-mix application of all the 4 combinations, viz. clodinofop + metsulfuron (60 + 2.5 g a.i./ha), sulfosulfuron + 2, 4-D and sulfosulfuron + metsulfuron (25 + 2.5 g a.i./ha) and sulfosulfuron + carfentrazone ethyl (25 + 20 g a.i./ha) remained at par with each other and significantly better than their alone application. This may be attributed better weed control, higher yield-attributing characters which resulted increase in grain and straw yields. The results are in close conformity with the results of Ashrafi *et al.,* (2009).

Economics

Highest net returns of ₹ 33,660/ha were recorded with clodinofop + metsulfuron (60 + 2.5g a.i./ha) closely followed by weed-free and sulfosulfuron + metsulfuron (25 + 2.5g a.i./ha) and sulfosulfuron + carfentrazone ethyl (25 + 20 g a.i./ha), which recorded more than ₹30,000 net returns/ha compared to lowest net returns of weedy check (₹12,110/ha). Singh (2012) also reported similar findings with tank-mix application of herbicides. Alone application of these herbicides also produced ₹11-13500 higher net returns/ha than weedy check. The maximum benefit: cost ratio of (2.72-2.91) was recorded with application of tank mix above herbicides against 2.64 benefit: cost ratio of weed free. This was mainly owing to lesser cost and better yields.

N, P and K uptake

Tank-mix application of clodinofop + metsulfuron (60 +2.5 g ai/ha), sulfosulfuron + 2,4-D and sulfosulfuron + metsulfuron (25 + 2.5 g a.i./ha) and sulfosulfuron + carfentrazone ethyl (25 + 20 g a.i./ha), being at par, recorded significantly higher N, P and K uptake by crop than rest of the treatments. This was mainly owing to better grain and straw yields observed under these treatments. Lowest N, P and K uptake by weeds was recorded with application of clodinofop + metsulfuron (60 +2.5g ai/ha) which being at par with almost all the other tank-mix ap-

Table 3. Effect of herbicide application on yield and yield attributing characters of wheat (mean of 2 years)

Treatment	Dose (g a.i./ha)	Effective tillers/m^2	Grains/ ear	1,000-grain weight (g)	Yield (t/ha)		Net returns (×10^3₹/ha)	Benefit: cost ratio
					Grain	Straw		
Sulfosulfuron	25	406	38.6	40.0	4.29	4.80	26.69	2.54
Clodinofop	60	407	38.7	39.9	4.31	4.83	26.79	2.54
Metribuzin	200	374	36.4	39.4	3.94	4.41	23.02	2.33
Mesosulfuron + Idosulfuron	10 + 2.4	393	37.9	39.1	4.24	4.75	25.81	2.48
Sulfosulfuron + 2, 4-D	25 + 400	435	41.3	41.6	4.75	5.32	31.26	2.79
Sulfosulfuron + Metsulfuron	25 + 2.5	444	40.7	41.6	4.81	5.39	32.98	2.91
Clodinofop + Metsulfuron	60 + 2.5	456	41.4	41.9	4.99	5.59	33.66	2.91
Sulfosulfuron + Carfentrazone ethyle	25 + 20	428	40.7	41.7	4.68	5.24	30.47	2.74
Weed free		461	42.9	42.5	5.17	5.79	33.09	2.64
Weedy check		284	36.3	38.3	2.83	3.17	12.11	1.71
SEm±		5.7	1.1	0.7	0.10	0.11	-	-
CD (P=0.05)		17	3.2	2.1	0.32	0.54	-	-

Table 4. Effect of herbicide application on nutrient uptake by wheat and weed (mean of 2 years data)

Treatment	Dose (g a.i./ha)	Nutrient uptake by wheat crop (kg/ha)			Nutrient uptake by weeds (kg/ha)		
		N	P	K	N	P	K
Sulfosulfuron	25	103.9	24.5	106.7	9.65	4.66	8.32
Clodinofop	60	104.7	24.8	105.6	9.78	4.99	9.38
Metribuzin	200	94.3	22.6	96.5	5.31	2.72	5.34
Mesosulfuron Isosulfuron	10 + 2.4	101.7	24.5	101.9	11.84	6.08	11.70
Sulfosulfuron + 2, 4-D	25 + 400	119.2	26.6	122.1	3.61	1.87	3.55
Sulfosulfuron + Metsulfuron	25 + 2.5	121.5	27.4	123.9	3.70	1.89	3.68
Clodinofop + Metsulfuron	60 + 2.5	125.2	27.7	128.3	2.61	1.35	2.61
Sulfosulfuron + Carfentrazone ethyle	25 + 20	116.6	26.9	120.2	3.18	1.63	3.15
Weed free		130.5	28.9	129.9	0.00	0.00	0.00
Weedy check		68.1	16.2	68.9	24.90	12.81	24.91
SEm±		2.2	0.6	2.8	0.54	0.30	0.35
CD (P=0.05)		6.4	1.9	7.4	1.63	0.91	1.07

plication of herbicideds and significantly lower than alone application of all herbicides. The highest N, P and K uptake was recorded under weedy check, indicating the extent of nutrient loss through weeds in wheat. Pandey *et al.* (2007) also reported highest depletion of N, P and K in weedy check plot.

Based on 2 years result at five locations of farmers field it may be concluded that weeds associated with zero-tilled irrigated wheat in rice–wheat cropping pattern of eastern Uttar Pradesh may be effectively managed through tank-mix application of clodinofop + metsulfuron (60 + 2.5g a.i./ha) applied as post-emergence (30 days after sowing). The effect of tank-mix application of clodinofop + metsulfuron (60 +2.5g ai/ha) was consistent and resulted highest grain yield and economic return. With this technology resources can be best utilized by the farmers of eastern Uttar Pradesh.

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