Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

J P P Journal of Pharmacognosy and Phytochemistry

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2016; 5(3): 138-141
Received: 23-03-2016
Accepted: 26-04-2016

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Study of herbicides and their tank mixture for controlling weeds in zero tilled wheat of eastern Uttar Pradesh

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Abstract
On farm trial was conducted during winter season of 2014-15 and 2015-16 to assess the efficacy of sulfosulfuron, clodinofop, metribuzin, mesosulfuran & idosulfuron and tank mixture of sulfosulfuron with 2,4-D, metsulfuron, carfentrazone ethyle and clodinofop with metsulfuron in zero tilled wheat (*Triticum aestivum* L. emend. Fiori & Paol). 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 (51.6 and 51.75 q/ha) were recorded with weed free plot which was at par with clodinofop + metsulfuron (60+2.5 g ai/ha). Uncontrolled growth of weeds caused 45.9 and 44.4 percent reduction in the crop yield compared to weed free treatment. Application of clodinofop with metsulfuron and sulfosulfuron + metsulfuron sulfosulfuron + carfentrazone ethyl, sulfosulfuron + 2,4-D proved better than their alone application resulting in 14.72 per cent yield increase when averaged over two years. Among the herbicides, clodinofop + metsulfuron remaining at par with sulfosulfuron+ metsulfuron, sulfosulfuron + 2, 4-D was most effective in enhancing yield attributes and grain yield. Highest economic return and B: C ratio was obtained using clodinofop with metsulfuron (Rs. 32285 and 35025/ha; 2.89 and 2.96 during 2014-15 and 2015-16, respectively). Application of metribuzin in spite of better weed control efficiency recorded lowest grain yield among the herbicides tested which was at par with mesosulfuron isosulfuron.

Keywords: Weed control, wheat, herbicides, yield, economics, sulfosulfuron, metsulfuron, clodinofop, carfentrazone ethyl

Introduction
Wheat (*Triticum aestivum* L. emend. Fiori & Paol) is a prime cereal crop and grown in 31.47 million hectare and production 90.8 mt in India. The productivity of wheat has increased tremendously in Indo Gangetic plains but now a days increasing population of little grass canary (*Phalaris minor* Retz) with broad leaf weeds causing substantial yield loss in rice - wheat cropping system. Weed which invade divest the crop of half of applied nitrogen (Chasalin & Timafeera 1974) [2] and considerable amount of other major and micro nutrients, thereby resulting in heavy yield reduction. Uncontrolled weeds reduce wheat yield to the time of 20- 50 % (Singh *et al*. 1997) [6]. Commonly used herbicides isoproturon and sulfosulfuron control grassy weeds only but had little effect on troublesome broad leaf weeds. Further continuous use of isoproturon has been reported to the development of resistant biotypes of *Phalaris minor* (Malik & Singh. 1995) [3]. 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 molecules with broad spectrum activity or their combination of available herbicide 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 and yield of zero till wheat in rice- wheat cropping system in eastern Uttar Pradesh.

Materials and methods
On farm trial in farmer's participatory mode was carried out during winter season at of 2014-15 and 2015-16 at cooperate farmer's field of Barabanki district of eastern plain zone in irrigated ecosystem. Trials were conducted at five farmer's field in 5 blocks. Soils were sandy loam to clay loam with 6.5 to 8.2 pH and 0.27 to 0.4 percent 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. There were 9 treatments in the trial namely sulfosulfuron, clodinofop, metribuzin, mesosulfuron & isosulfuran, sulfosulfuron + 2, 4-D, sulfosulfuron + metsulfuron, sulfosulfuron + carfentrazone ethyle, weed free and weedy check.

The area of each treatment was of 500 m^2 at 5 locations as replications. Wheat HD 2967 was sown on mid of November during both the years with the help of zero till machine using 100 kg seed /ha. Herbicide were applied as post emergence (25 DAS) with knap sack sprayer fitted with flat fan nozzle using 500 litres of water/ha. Weed population (m^2) and weed dry weight (g/m^2) were recorded at 50 days after sowing (DAS) by placing a quadrate of 1 x 1 m twice in a plot. The data on weed count and dry matter were transformed to square root x + 0.5 and then analyzed statistically.

Result and discussion

Weed Species

The weed flora observed in weedy check plot at 50 DAS was *Phalaris minor* Retz. 42.87 and 49.64 percent, *Avena ludovician* 8.66 and 7.08, *Chenopodium album* 22.67 and 22.88 percent, *Solonum nigrum* 11.51 and 8.98 percent *Fumaria parviflora* Lam 12.25 and 10.37 percent during 2014-15 and 2015-16, respectively. 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 50 DAS (Table-1) revealed that the application of clodinofop (60 g ai/ha) alone or with metsulfuron gave effective control of grassy weeds *Phalaris minor* and *A. ludoviciana* which was significantly superior compared meso isosulfuron but at par with rest of the herbicides alone or in combination. The application of sulfosulfuron, clodinofop and meso isosulfuron didn't provide any control of the broad leaved 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 population and dry weight

Different weed control treatments significantly decreased the total number of weeds and their dry weights compared to weedy check at 50 DAS during both the crop seasons (Table-2). Among the herbicides, application tank mixture of clodinofop + metsulfuron (60 +2.5g ai/ha), though being on par with either tank mix application of sulfosulfuron + 2,4-D (25 + 400 g ai/ha), Sulfosulfuron + metsulfuron (25 + 2.5 g ai/ha) and sulfosulfuron + carfentrazone ethyl (60 + 20 ai/ha) or application of metribuzin (200 g ai/ha) alone reduced the weed population significantly than the weedy check and other herbicidal treatments during both the year at 50 DAS during both the seasons. Similar trend was observed with all the herbicides in reduction of dry weight of weeds during both the years of experimentation. This may be because of tank mixture of clodinofop with metsulfuron and sulfoslfuron with either 2, 4-D or metasulfuron and carfantrazone may have acted synergistically in broadening the spectrum of weed control. These results are in close conformity with these Punia *et al*. (2004) [4]. Among different herbicidal treatments, highest weed control efficiency of 88.7 and 90.7 percent was observed with clodinofop + metsulfuron (60 +2.5g ai/ha) during first and second year respectively followed by sulfosulfuron + carfentrazone ethyl (60 + 20 ai/ha), sulfosulfuron + 2, 4-D (25 + 400 g ai/ha) and Sulfosulfuron + metsulfuron (25 + 2.5 g ai/ha). Lowest weed control efficiency was recorded with meso isosulfuron (58.87 & 63.06 %). Higher weed control efficiency may be due to lower weed dry weight. The poor efficiency of meso isosulfuron might be due to persistence of high moisture in the field after application of herbicide.

Weed Index

Among herbicides, clodinofop + metsulfuron (50 +2.5g ai/ha) lowest weed index followed by Sulfosulfuron + metsulfuron (25 + 2.5 g ai/ha), sulfosulfuron + 2, 4-D (25 + 400 g ai/ha) and sulfosulfuron + carfentrazone ethyl (60 + 20 ai/ha) indicating their effectiveness in controlling weeds. The high weed index was recorded with metribuzin due to poor grain yield owing to its adverse effect on crop.

Yield attributes

Weed management treatment significantly improved the effective tillers of wheat in both the years of trial. The highest number of fertile tillers was recorded with weed free treatment which was comparable with clodinofop + metsulfuron and Sulfosulfuron + metsulfuron. Treatment weed free, clodinofop + metsulfuron, sulfosulfuron + 2, 4-D and Sulfosulfuron + metsulfuron recorded significantly higher fertile tillers compared to rest of the herbicidal treatment tested. Among the herbicide tested lowest fertile tillers were recorded with application of metribuzin. It might be due to its phytotoxic effect on crop during early crop growth stage. Weed free treatment, sulfosulfuron + 2,4-D and Sulfosulfuron + metsulfuron sulfosulfuron + carfentrazone recorded significantly higher number of grain and test weight over alone application of clodinofop, metsulfuron, sulfosulfuron, meso isosulfuron and metribuzin. However they were found at par each other. It was owing to less weed competition in these herbicidal treatments. Alone application of clodinofop, metsulfuron, sulfosulfuron, meso isosulfuron and metribuzin fail to produce any difference with weedy check in respect of these parameters. It was attributed to the increase in competition by broad leaf weeds with the crop for light water, nutrients and space etc.

Yield

All the weed control treatments significantly improved the grain yield, net return and B:C ratio compared to weedy check (Table 3). The yield improvement due to weed management through different herbicide varied according to their efficacy. Further highest grain yield was recorded with weed free treatment followed by clodinofop + metsulfuron (60 +2.5g ai/ha), Sulfosulfuron + metsulfuron (25 + 2.5g ai/ha) and sulfosulfuron + 2, 4-D (25 + 400 g ai/ha) which were at par but significantly higher compared to rest of the weed management treatments excepts application of sulfosulfuron + carfentrazone ethyle. Application of sulfosulfuron + carfentrazone ethyl (60 + 20 g ai/ha) produced higher grain yield over alone application of clodinofop, metsulfuron, sulfosulfuron, meso isosulfuron, metribuzin and weedy check. These results are in close conformity with the results of Bharat and Kachroo (2007) [1]. Application of metribuzin (200 g ai/ha) resulted in lower yield despite of good weed control efficiency than sulfosulfuron during 2014-15 and sulfosulfuron, clodinofop and meso-isosulfuron during 2015-16 was due its phytotoxic effect on crop as evident from less effective tillers. Sharma (2003) [7] and Bharat and kachroo (2007) [1] also reported phytotoxic effect of metribuzin on wheat. The maximum reduction in wheat yield due to weeds was recorded 45.9 and 44.4 per cent in weedy check and

minimum with clodinofop + metsulfuron 4.43 and 2.41 percent respectively, during both the years.

Economics

The net return and B:C ratio as influenced by different herbicidal treatment (Table 3) reveals that highest net return (Rs.32285 and 35025/ha) were recorded with clodinofop + metsulfuron (50 +2.5 g ai/ha) followed by weed free plot. Though highest B:C ratio was obtained with clodinofop + metsulfuron (60 +2.5 g ai/ha) followed by Sulfosulfuron + metsulfuron (25 + 2.5 g ai/ha) and sulfosulfuron + 2, 4-D (25 + 400 g ai/ha) respectively, and the minimum in weedy check. NP and K uptake by wheat at harvest: Weed control treatments significantly increased the uptake of nutrients by crop than the weedy check. Highest nutrient uptake was recorded with weed free treatment which was on par with the application of clodinofop + metsulfuron (60 +2.5g ai/ha) but significantly superior over rest of the treatments tested during both the years of experiments. Among the herbicides tested clodinofop + metsulfuron (60 +2.5g ai/ha) at par with sulfosulfuron + metsulfuron (25 + 2.5 g ai/ha) and sulfosulfuron + 2, 4-D (25 + 400 g ai/ha) recorded significantly higher uptake of N P and k during both the years. Tank mixture application of herbicide proved their superiority over alone application of herbicide in respect to nutrient uptake by wheat.

Lowest nutrient uptake by weeds was recorded with the application of clodinofop + metsulfuron (60 +2.5 g ai/ha) which was on par with the application of Sulfosulfuron + metsulfuron (25 + 2.5 g ai/ha) and sulfosulfuron + 2, 4-D (25 + 400 g ai/ha). Application of metribuzin recorded markedly lower nutrient depletion by weeds compared to sulfosulfuron, clodinofop and meso-isosulfuron. Reduction in biomass of weeds might be the reason for lower nutrient depletion under these treatments.

Table 1: Density of different weeds as influenced by different herbicides at 50 DAS

Treatments	Dose (g ai /ha)	*Phalaris minor*		*Avena ludoviciana*		*Chenopodium album*		*Solanum nigrum*		*Fumaria parviflora*	
		Y_1	Y_2	Y_1	Y^2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
Sulfosulfuron	25	2.17 (4.25)	2.06 (3.75)	1.89 (3.10)	1.58 (2.00)	3.97 (15.32)	4.81 (22.65)	2.49 (5.72)	3.09 (9.10)	2.27 (4.66)	2.01 (3.57)
Clodinofop	60	1.66 (2.25)	1.61 (2.10)	1.20 (0.94)	1.30 (1.21)	4.44 (19.22)	4.89 (23.42)	3.01 (8.61)	3.24 (10.00)	3.02 (8.67)	3.13 (9.32)
Metribuzin	200	2.38 (5.20)	2.96 (8.30)	2.14 (4.10)	2.58 (6.20)	1.73 (2.50)	1.81 (2.80)	1.89 (3.10)	1.89 (3.00)	1.68 (2.32)	1.74 (2.53)
Mesosulfuron Isosulfuron	10 + 2.4	2.80 (7.33)	2.88 (7.84)	2.49 (5.70)	2.26 (4.62)	4.50 (19.80)	4.59 (20.62)	2.96 (8.32)	2.95 (8.24)	3.05 (8.82)	3.11 (9.22)
Sulfosulfuron + 2,4-D	25 + 400	1.89 (3.10)	1.72 (2.46)	2.05 (3.72)	1.99 (3.48)	1.58 (2.00)	1.89 (3.10)	2.07 (4.66)	2.49 (5.72)	1.83 (2.87)	1.56 (1.95)
Sulfosulfuron + Metsulfuron	25 + 2.5	2.06 (3.75)	2.00 (3.50)	2.02 (3.60)	2.01 (3.56)	1.90 (3.12)	2.04 (3.67)	2.52 (5.86)	2.66 (6.60)	1.87 (3.00)	1.66 (2.25)
Clodinofop + Metsulfuron	60 + 2.5	1.66 (2.20)	1.76 (2.61)	1.26 (1.10)	1.26 (1.00)	1.92 (3.20)	1.89 (3.10)	1.87 (3.00)	1.92 (3.19)	1.22 (1.00)	1.22 (1.00)
Sulfosulfuron + Carfentrazone ethyle	25 + 20	1.73 (2.50)	1.79 (2.71)	1.43 (1.56)	1.63 (2.15)	2.06 (3.75)	2.09 (3.86)	2.16 (4.16)	1.91 (3.15)	1.61 (2.10)	1.64 (2.19)
Weed free		0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
Weedy check		5.75 (32.65)	6.43 (40.83)	2.63 (6.45)	2.49 (5.71)	4.25 (17.63)	4.44 (19.25)	3.13 (9.32)	2.78 (7.25)	2.78 (8.38)	2.82 (7.56)
CD (P =0.05)		0.05	0.64	0.62	0.58	0.49	0.67	0.72	0.78	0.63	0.59

Y_1 = 2014-15 and Y_2= 2015-16

Table 2: Effect of herbicide on weed population, weed dry weight and weed control efficiency at 50 DAS

Treatments	Dose (g ai /ha)	Weed population (no./m^2)		Weed dry weight (g/m^2)		Weed control efficiency (%)		Weed index	
		Y_1	Y_2	Y_2	Y_2	Y_1	Y_2	Y_1	Y_2
Sulfosulfuron	25	5.79 (33.05)	6.40 (41.07)	6.38 (40.25)	7.08 (49.76)	63.95	60.42	17.2	16.5
Clodinofop	60	6.34 (39.69)	6.82 (46.05)	6.39 (40.43)	7.13 (50.46)	63.78	59.86	18.0	15.2
Metribuzin	200	4.20 (17.22)	4.83 (22.85)	4.78 (22.38)	5.39 (28.56)	79.95	77.28	23.2	24.34
Mesosulfuron Isosulfuron	10 + 2.4	7.12 (50.51)	7.14 (50.54)	7.51 (55.91)	7.54 (56.42)	58.87	63.06	19.2	17.4
Sulfosulfuron + 2,4-D	25 + 400	4.10 (16.35)	4.15 (16.71)	4.08 (16.15)	4.33 (18.25)	85.53	85.48	9.30	6.80
Sulfosulfuron + Metsulfuron	25 + 2.5	4.45 (19.33)	4.48 (19.58)	4.22 (17.32)	4.31 (18.12)	84.48	85.68	6.8	6.4
Clodinofop + Metsulfuron	60 + 2.5	3.31 (10.50)	3.37 (10.9)	3.61 (12.6)	3.58 (12.32)	88.71	90.20	4.4	2.4
Sulfosulfuron + Carfentrazone ethyle	25 + 20	1.73 (2.50)	1.79 (2.71)	1.43 (1.56)	1.63 (2.15)	86.07	88.33	10.5	8.6
Weed free		0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)		100	-	-
Weedy check		5.75 (32.65)	6.43 (40.83)	2.63 (6.45)	2.49 (5.71)	-	-		-
CD (P =0.05)		0.05	0.64	0.62	0.58				

Y_1 = 2014 -15 and Y_2= 2015-16

Table 3: Effect of herbicide application on yield and yield attributing characters of wheat

Treatments	Dose (g ai /ha)	Effective Tillers (no./m^2)		Grains/ear (No.)		1000 grain weight (g)		Yield (q/ha)			Net return (Rs./ha)		B:C ratio	
		Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Mean	Y_1	Y_2	Y_1	Y_2
Sulfosulfuron	25	401	410	38.61	38.50	39.90	40.12	42.70	43.20	42.95	25835	27535	2.53	2.54
Clodinofop	60	396	417	38.60	38.70	39.79	40.05	42.31	43.89	43.10	25385	28199	2.50	2.58
Metribuzin	200	367	381	36.30	36.50	39.40	39.35	39.64	39.15	39.39	22775	23282	2.35	2.30
Mesosulfuron Isosulfuron	10 + 2.4	390	396	37.80	38.15	39.10	39.15	41.68	42.75	42.40	24690	26937	2.45	2.50
Sulfosulfuron +2, 4-D	25 + 400	434	435	41.15	41.50	41.23	42.00	46.80	48.20	47.50	29835	32685	2.76	2.82
Sulfosulfuron + Metsulfuron	25 + 2.5	442	446	40.82	40.68	41.47	41.65	48.10	48.15	48.12	31000	34965	2.88	2.93
Clodinofop + Metsulfuron	60 + 2.5	452	460	41.20	41.60	41.67	42.20	49.31	50.50	49.90	32285	35025	2.89	2.94
Sulfosulfuron + Carfentrazone ethyle	25 + 20	426	430	40.75	40.60	41.35	42.10	46.21	47.31	46.76	29250	31690	2.72	2.76
Weed free		460	462	42.65	43.10	42.40	42.60	51.60	51.75	51.67	31985	34187	2.59	2.69
Weedy check		288	280	36.32	36.25	38.00	38.50	27.90	28.78	28.34	11435	12794	1.69	1.73
CD (P = 0.05)		18	16	3.30	3.15	2.10	2.06	3.00	3.12					

Y_1 = 2014 -15 and Y_2= 2015-16

Table 4: Effect of herbicide application on yield and yield attributing characters of wheat

Treatments	Dose (g ai /ha)	Nutrient uptake by wheat crop (kg/ha)						Nutrient uptake by weeds (kg/ha)					
		N		P		K		N		P		K	
		Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
Sulfosulfuron	25	102.48	105.41	24.34	24.62	105.47	108.00	9.45	9.85	4.30	5.02	7.48	9.15
Clodinofop	60	101.94	107.53	24.11	25.45	102.81	108.40	8.77	10.79	4.44	5.55	8.28	10.49
Metribuzin	200	94.74	93.91	22.59	22.70	96.32	96.70	4.69	5.94	2.39	3.05	4.69	5.99
Mesosulfuron Isosulfuron	10 + 2.4	100.44	103.02	24.17	24.79	101.11	102.86	11.79	11.90	6.08	6.09	11.68	11.73
Sulfosulfuron + 2, 4-D	25 + 400	118.40	120.05	26.20	26.99	120.27	123.87	3.39	3.83	1.74	2.00	3.34	3.77
Sulfosulfuron + Metsulfuron	25 + 2.5	121.21	121.81	27.12	27.77	123.61	124.22	3.60	3.80	1.85	1.94	3.61	3.76
Clodinofop + Metsulfuron	60 + 2.5	124.75	125.74	27.41	27.92	126.72	129.78	2.64	2.58	1.36	1.34	2.65	2.57
Sulfosulfuron + Carfentrazone ethyle	25 + 20	116.91	116.38	26.33	27.43	118.75	121.58	3.28	3.09	1.68	1.58	3.26	3.05
Weed free		130.03	130.92	28.89	28.98	129.51	130.41	0.00	0.00	0. 00	0.00	0.00	0.00
Weedy check		66.68	69.46	15.90	16.40	68.91	69.07	23.44	26.37	12.05	13.57	23.55	26.27
CD (P =0.05)		6.66	6.10	1.87	1.89	7.34	7.52	1.72	1.54	0.91	0.92	1.11	1.04

Y_1 = 2014 -15 and Y_2= 2015-16

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