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Weed management in late sown wheat (*Triticum aestivum*) after rice (*Oryza sativa*) in rice-wheat system in rainfed lowland

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ABSTRACT

To study the efficacy of different herbicides, tillage practices and weed control measures on late sown wheat (*Triticum aestivum* L. emend. Fiori & Paol) field experiments were conducted during winter of 2004-05 to 2006-07 at Ghaghraghat (Bahraich) in Uttar Pradesh. Significantly lower density, weight, and nutrient uptake by weeds was recorded with isoproturon + 2,4-D (0.75 + 0.6 kg/ha) resulting in higher mean grain yield (3.89 tonne /ha) and net income (Rs. 18,375/ha). Weed free treatment recorded the highest energy output and lowest energy use efficiency (EUE). Isoproturon + 2, 4-D resulted in the highest EUE and energy productivity followed by metribuzin. Conventional tillage (CT) significantly increased density and dry matter of weeds when compared with zero tillage (ZT), thus, ZT increased grain yield of wheat by 2.18% as compared to CT. Sulfosulfuron (25 g/ha) recorded the lower density and dry weight of weeds and higher weed suppression efficiency (83.43%) followed by isoproturon + 2,4-D (81.04%). Application of isoprturon + 2,4-D produced significantly higher grain yield in ZT, and sulfosulfuron in CT. Irrespective of tillage, isoproturon + 2,4-D gave the highest net income (Rs 17.12 x 10^3/ha) and benefit : cost ratio (2.59). CT consumed 23.66% more energy than ZT. The EUE and energy productivity was highest with ZT and sulfosulfuron.

Key words: Herbicides, Lowland, Rice, Weeds, Wheats, Zero tillage

Wheat (*Triticum aestivum* L. emend. Fiori & Paol) occupies prime position among the food crops of the world. In India it covers an area of 27 million ha with a total production of 78.4 million tonnes (average yield of 2.93 tonne/ha). During the post-green revolution the productivity of wheat has increased and it is far below the potential (11.2 t/ha) yield (Jat *et al.,* 2003). Of the various constraints to low productivity of wheat, delayed sowing and weed infestation have been recognized as important ones.

In lowland areas, late transplanting of long duration varieties and high soil moisture after rice delays the sowing of wheat. Conventional method of wheat sowing by giving repeated tillage further delays the sowing that further reduces the yield. Uncontrolled weed growth may reduce wheat yield ranging from 15-40% depending upon magnitude, nature and duration of weed infestation (Jat *et al.,* 2003).

Zero till (ZT) technology advances the sowing of wheat crop in high moisture areas after rice and also reduces the incidence of *Phalaris minor* (Brar and Walia, 2007). Control of weeds manually in wheat though effective and easy but unavailability of labour at right time and high wages makes it difficult, costly and uneconomical.

Continuous use of isoproturon has led to development of resistance in *P. minor* in wheat (Malik and Singh, 1995). Sulfosulfuron, isoproturon+ 2,4-D, and metribuzin effectively controls weeds in wheat under conventional tillage (CT) system (Pandey *et al.,* 2006). However, very little information is available on the effect of these herbicides on weeds in wheat under both ZT and CT systems particularly in rainfed lowlands after rice. Hence, the present experiment was planned to study the efficacy of different herbicide alone as well as under ZT and CT in wheat grown after rice in rainfed lowlands.

MATERIALS AND METHODS

To study the bioefficacy of different herbicides on weed control in wheat first field experiment was conducted during winter season for 3 years from 2004-05 - 2006-07 at the Crop Research Station of Narendra Deva University of Agriculture & Technology, Ghaghraghat, (81^0 20' N latitude, 27^0 50' E longitude and located at 112 above mean sea level) Bahraich, Uttar Pradesh. The soil of experimental site was sandy-loam with pH 8.1, low in organic carbon (0.42%), medium in available P (18.4 kg/ha) and K (185 kg/ha). The eight treatments comprised of

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farmers practice (one hand-weeding at 35 days after sowing (DAS), fenoxaprop-p-ethyl (100 g/ha), sulfosulfuron (25 g/ha), metribuzin (200 g/ha), isoproturon + 2,4-D (0.75 + 0.60 kg/ha), two hand weedings at 20 and 40 DAS alongwith weed free and weedy check were laid out in a randomized block design with four replications. 'HUW 234' wheat was sown in lines at 20 cm apart by *kera* method using 125 kg/ha seed on 18 December in all the 3 years.

Second field experiment was conducted on 6 and 4 farmers' field which were sandy loam with pH 8.2, organic carbon (0.44%), medium in P (18.5 kg/ha) and K (180.6 kg/ha) during 2005-06 and 2006-07. The 10 treatments comprised of 2-tillage practices zero tillage (ZT) - sowing of wheat, and conventional tillage (CT) – two harrowing + 2 ploughing by cultivator and planking after each ploughing and 5 weeds control measures (weedy check, isoproturon + 2,4-D at 0.75+0.6 kg/ha, metribuzin at 200 g/ha, sulfosulfuron at 25 g/ha) and farmers practice (one hand weeding at 35 DAS) were tested in factorial randomized block design keeping 6 and 4 farmers field as replication in respective years. Rice was harvested manually with sickle at a height of 5-10 cm from ground surface. 'HUW 234' wheat was sown on 30 November to 7 December in 2005, and 3-12 December in 2006 using seed rate of 125 kg/ha. The plot size was 20 m x 10 m.

In both experiments recommended dose of fertilizers 120 - 26.4 - 49.8 kg N-P-K/ha was uniformly applied to all the treatments. Full dose of P and K as single super phosphate and muriate of potash, and half dose of N through urea was applied as basal at sowing, and rest N was given in 2 equal splits by top dressed after first irrigation and booting stage during all years. The crop was raised with all recommended package of practices. All herbicides were applied at 35 DAS with manually operated knapsack sprayer fitted with flat fan nozzle using 500 liters of water/ha in both experiments.

The energy input, energy output, energy use efficiency and energy productivity was calculated by using constant and procedures given by Devasenpathy *et al.* (2009). Observations on density and dry weight of weeds were recorded in each plot from two quadrates each measuring 50 cm x 50 cm at 90 and 120 DAS in first experiment and 90 DAS in second experiment. The weeds were separated species wise and grouped as grassy and broad leaved weed and their respective numbers were counted in second experiment. These samples were first sun dried and then dried in oven at 70^{0}C until constant weight was attained. The data of weed density and dry weight were subjected to square root transformation using formula $\sqrt{x + 0.5}$ before statistical analysis. Crop was harvested manually in last week of April in each year. The grain yield data was reported at 14% grain moisture.

Table 1. Weed density, dry weight, weed suppressing efficiency (WSE) and nutrient uptake by weeds (kg/ha) as affected by weed control treatments (mean of 3 years)

Weed control treatment	Weed density / (No./m^2)		Weed dry weight (g/m^2)		WSE (%)		Nutrient uptake by weeds					
							90 DAS			120 DAS		
	90 DAS	120 DAS	90 DAS	120 DAS	90 DAS	120 DAS	N	P	K	N	P	K
Farmers practice	14.51	14.14	14.23	16.20	33.5	31.6	38.2	19.2	37.3	49.2	24.6	48.7
	(210.3)	(199.7)	(202.0)	(262.0)								
Fenoxa prop-p-ethyl	11.00	10.72	10.88	12.60	61.2	58.7	22.4	11.3	21.7	30.2	15.0	29.4
	(120.7)	(114.6)	(118.0)	(158.0)								
Isoproturon + 2,4-D	9.48	9.23	9.24	10.90	72.0	68.6	16.1	8.1	15.5	22.6	11.4	22.0
	(89.5)	(84.7)	(85.0)	(119.0)								
Sulfosulfuron	10.05	9.75	10.31	12.06	65.3	62.1	19.9	9.9	19.4	27.5	13.8	26.5
	(100.6)	(94.6)	(106.0)	(145.0)								
Metribuzin	9.91	9.61	9.92	11.85	67.8	63.4	18.5	9.3	18.0	26.3	13.4	25.8
	(97.8)	(91.9)	(98.0)	(140.0)								
Two hand weeding	7.82	7.62	2.58	9.46	79.6	76.8	11.7	5.9	10.6	16.9	8.6	19.8
20 and 40 DAS	(60.7)	(57.6)	(62.0)	(89.0)								
Weed free	0.00	0.00	0.00	0.00								
Weedy check	17.61	17.16	17.44	19.58								
	(309.7)	(294.2)	(304.0)	(383.0)			55.9	28.9	52.9	70.9	36.8	67.6
SEm ±	1.98	1.86	0.71	0.73	1.9	2.0	2.2	2.5	1.6	1.5	2.3	2.5
CD (P=0.05)	4.86	4.66	1.78	01.94	4.9	5.2	5.6	6.3	4.2	3.7	5.8	6.3

Figures in parentheses are original value
DAS, Days after sowing

RESULTS AND DISCUSSION

Experiment-I

Weed growth

The major weed flora recorded in weedy check plot from both experimental sites along with their relative density of grassy weeds like *Phalaris minor* (L.) Retz (46.5%), *Avena fatua* L. (8.7%), *Cynodon dactylon* L. (14.8%), the broad leaf weeds, *Chenopodium album* L. (12.6%), *Anagalis arvensis* L. (8.1%), *Melilotus alba* L. (1.6%), *Melilotus indica* L. (1.5%), *Circium arvensis* L. (3.5%) and *Fumaria parviflora* L. (2.7%) were present in low density as compared to grassy weeds.

The density of weeds was less at 120 than that of 90 DAS stage (Table 1). This was mainly due to mortality of weed plants at 120 DAS. All weed control treatments reduced the density and dry weight of weeds when compared with weedy check. Two-hand weedings resulted in lowest density (60.7 and 57.6/m^2) and dry weight of weeds (25.8 and 30.6 g/m^2) at 90 and 120 DAS, respectively. Among the herbicides, isoproturon+ 2,4-D resulted in the lowest density (89.5 and 84.7 /m^2) and dry weight of weeds (85 and 119 g/m^2) at 90 and 120 DAS, respectively followed by metribuzin, sulfosulfuron and fenoxaprop-p-ethyl. The highest weed suppression efficiency (79.6% and 76.8%) was recorded with 2 hand weedings followed by isoproturon + 2,4-D (72.0% and 68.6%) at 90 and 120 DAS, respectively.

The nutrient uptake through weeds was affected significantly by various weed control measures (Table 1). Among the herbicides, the lowest nutrient uptake through weeds was recorded with isoproturon + 2,4-D followed by metribuzin and sulfosulfuron which was mainly due to significantly lower dry weight of weeds. However, highest uptake was recorded with fenoxa prop-p-ethyl because of higher weed dry weight due to poor control of weeds.

Yield attributes and yield

Weed free check resulted the maximum effective tillers /m^2, grains / spike and test weight of wheat when compared with rest of the treatments (Table 2). Among the herbicides, isoproturon + 2,4-D gave the maximum values of the yield attributes, and grain yield (4.13, 3.85, 3.69 and 3.89 t/ha in respective years and on pooled basis) followed by metribuzin and sulfosulfuron mainly due to effective control of weeds as evidenced by lower density and dry weight of weeds (Table 1). Similar results were obtained by Pandey *et al.* (2007).

Weedy check resulted in significant reduction in grain yield (39.8%) followed by farmers' practice (35.1%) (Table 2). Among the herbicides, the lowest reduction in grain yield (4.11%) was registered with isoproturon + 2,4-D while the maximum reduction (11.97%) being observed with fenoxa prop-p-ethyl.

Economics and energetics

The highest net income and benefit : cost ratio (2.37) was recorded with isoproturon + 2,4-D owing to lower cost of cultivation and higher yield. The farmers practice and weedy check resulted in the lowest net income and benefit : cost ratio due to lower yield.

Weed free treatment recorded higher energy output but lowest energy use efficiency and energy productivity due to higher energy input in comparison to energy output. Two hand weeding treatment registered the lowest energy productivity. Among the herbicidal treatment, higher energy use efficiency and energy productivity was recorded with isoproturon + 2,4-D followed by metribuzin. This is mainly due to higher energy out put owing to higher yield (Table 3).

Table 2. Yield attributes and yields of wheat and weed index as affected by different weed control treatments (mean of 3 years)

Weed control treatment	Plant height (cm)	Effective tillers (no./m^2)	Grains/ spike	Test weight (g)	Biological yield (t/ha)	Grain yield (t/ha) 2004-05	2005-06	2006-07	WI (%)
Farmers practice	88	288	34.2	38.1	2.7	2.6	2.5	7.1	35.1
Fenoxa prop-p-ethyl	87	297	37.4	38.5	3.7	3.6	3.4	8.8	12.0
Isoproturon + 2,4-D	88	310	43.8	40.6	4.1	3.8	3.7	9.5	4.1
Sulfosulfuron	89	322	45.9	40.7	3.9	3.8	3.6	9.3	6.2
Metribuzin	89	301	41.6	39.9	4.0	2.8	3.7	9.4	5.0
Hand weeding 20 and 40 DAS	89	320	42.6	40.5	3.6	3.5	3.7	8.8	14.3
Weed free	88	348	49.8	40.9	4.2	4.1	3.9	9.8	
Weedy check	88	247	32.3	36.7	2.6	2.4	2.3	6.8	39.8
SEm ±	0.4	3	1.2	0.3	0.1	0.1	0.1	0.2	
CD (P=0.05)	1	7	3.1	0.8	0.3	0.2	0.3	0.5	

DAS, Days after sowing

Table 3 . Economics (x10^3 Rs/ha) and energetics as affected by different weed control treatment (mean of 3 years)

Weed control treatment	Cost of cultivation	Net income	B:C ratio	Energy input (MJx10^3/ha)	Energy output (MJx10^3/ha)	Energy use efficiency	Energy productivity (kg/MJ)
Farmers practice	13.76	8.26	0.60	18.5	94.53	5.10	0.142
Fenoxa prop-p-ethyl	13.87	15.36	1.10	18.2	118.43	6.50	0.196
Isoproturon + 2,4-D	13.36	18.38	1.37	19.0	127.40	6.70	0.204
Sulfosulfuron	14.98	16.07	1.07	18.9	124.67	6.59	0.201
Metribuzin	13.38	18.08	1.35	18.9	126.62	6.69	0.204
Hand weeding 20 and 40 DAS	14.63	13.97	0.95	28.3	117.35	4.14	0.120
Weed free	15.21	17.70	1.16	38.6	131.26	3.40	0.141
Weedy check	12.90	7.71	0.59	18.8	90.34	4.80	0.130
SEm ±		0.55	0.09	0.90	4.30	0.30	0.009
CD (P=0.05)		1.63	0.28	2.50	10.50	0.78	0.022

Table 4. Yield attributes of wheat and weed growth as affected by tillage and weed control treatments (mean of 3 years)

Treatment	Plant height (cm)	Effective tillers /m^2	Grains/ spike	Test weight (g)	Weed density (No/m^2) *			Weed dry weight (g/m^2)*			WSE (%)	Weed index (%)
					Grassy	BLW	Total	Grassy	BLW	Total		
Tillage method												
Zero	86	315	48.7	40.9	7.79	5.53	9.52	8.42	6.25	10.46		
					(60.3)	(30.1)	(90.4)	(70.4)	(38.6)	(109.0)		
Conventional	88	289	46.3	40.2	9.48	6.38	11.08	7.72	5.07	9.21		
					(80.5)	(40.3)	(120.8)	(59.2)	(25.2)	(84.4)		
SEm ±	0.4	4	0.9	0.4	0.20	0.42	0.56	0.20	0.35	0.39		
CD (P=0.05)	1.1	10	2.3	1.1	0.50	1.20	1.40	0.60	0.90	1.00		
Weed control												
Weedy check	80	240	32.8	36.9	12.68	8.43	15.20	13.06	8.13	15.63		
					(160.4)	(70.7)	(231.1)	(170.3)	(65.6)	(235.9)		43.59
Sulfosulfuron	88	317	48.5	40.7	4.56	3.88	5.94	4.61	4.32	6.28		
					(20.3)	(14.6)	(34.9)	(20.8)	(18.2)	(39.0)	83.46	
Isoproturon	87	311	87.6	40.5	5.35	4.44	6.92	4.54	4.70	6.50		
+ 2,4-D					(28.2)	(19.3)	(47.5)	(20.2)	(21.6)	(41.8)	81.04	2.02
Metribuzin	86	295	85.2	39.5	6.17	5.00	7.91	5.21	5.01	7.20		
					(37.6)	(24.6)	(62.2)	(26.7)	(24.7)	(51.4)	78.21	3.62
Farmers practice	84	255	35.3	37.8	9.54	6.41	11.48	9.26	6.76	11.45		
					(90.7)	(40.6)	(131.3)	(85.3)	(45.3)	(130.6)	44.63	23.05
SEm ±	1	22	0.9	0.4	0.2	0.2	0.3	0.28	0.24	0.33		
CD (P=0.05)	2	59	2.5	1.0	0.7	0.6	0.8	0.71	0.62	0.90		

*Figures in parentheses indicates the original value; * at 90 DAS; BLW; broad leaved weeds; WSE, Weed Suppressing efficiency
DAS, Days after sowing

Experiment – II

Weed growth

The density and dry weight of both grassy and broad leaved weeds were higher under the CT when compared with ZT (Table 4). CT brought about the weed seeds from deeper soil to the upper surface during ploughing resulting in higher weed seeds germination. Under ZT, the germination of weeds was found lesser due to less soil disturbance. Brar and Walia (2007) also reported lower density and dry weight of weeds in ZT wheat. Sulfosulfuron resulted in significantly the lowest density and dry weight of weeds when compared with rest of the treatments, however, it was on par with isoproturon + 2,4-D with regards to weed dry weight. The highest weed suppression efficiency (83.46%) was recorded with sulfosulfuron followed by isoproturon +2,4-D (81.04%) and metribuzin (78.27%) owing to lowest weed dry weight. Farmers' practice had the lowest WSE (44.63%) owing to higher weed dry weight. Weed competition till maturity reduced the grain yield to the tune of 43.6%. Sulfosulfuron, isoproturon + 2,4-D and metribuzin increased the wheat grain yield by 43.49, 41.94 and 41.37%, respectively when compared with weedy check.

Table 5. Yield, economics (x 10^3 Rs/ha) and energetics as affected by tillage and weed control treatments (mean data)

Treatment	Grain yield (t/ha)		Biological yield (t/ha)		Cost of cultivation	Net income	B:C ratio	Energy input (MJ x 10^3/ha)	Energy output (MJ x 10^3/ha)	Energy use efficiency	Energy productivity (kg/MJ)
	2005-06	2006-07	2005-06	2006-07							
Tillage method											
Zero	3.3	3.2	8.0	7.8	10.35	15.38	1.47	16.9	105.7	6.25	0.192
Conventional	3.2	3.0	7.9	7.4	11.65	12.61	1.07	20.9	102.7	4.91	0.148
SEm ±	0.04	0.1	0.1	0.1		0.75	0.11	1.6	1.0	0.43	0.014
CD (P=0.05)	0.10	0.2	NS	0.4		1.80	0.24	3.5	2.2	0.98	0.032
Weed control											
Weedy check	2.1	2.0	5.1	4.8	10.37	5.64	0.56	18.0	66.6	3.54	0.111
Sulfosulfuron	3.7	3.6	9.1	8.5	10.82	17.12	1.59	18.9	118.6	6.27	0.193
Isoproturon + 2,4-D	3.6	3.4	8.7	8.3	10.66	16.72	1.58	19.0	117.7	6.19	0.189
Metribuzin	3.5	3.4	9.0	8.7	12.17	16.52	1.37	18.8	113.6	6.01	0.187
Farmers practice	2.8	2.6	6.2	6.0	11.92	8.96	0.75	18.5	82.1	4.44	0.147
SEm ±	0.1	0.1	0.2	0.3		1.23	0.06	0.2	4.8	0.32	0.012
CD (P=0.05)	0.2	0.3	0.6	0.7		2.95	0.14	0.4	11.6	0.86	0.028

DAS, Days after sowing

Yield attributes and yield

The plant height of wheat under CT was higher than that of ZT (Table 4) due to heavy competition between crop and weeds. ZT resulted in higher values of all yield attributes (effective tillers/m^2, grains/spike and test weight) of wheat when compared with CT. The lower density and dry weight of weeds under ZT reduced the crop-weed competition which had favoured the higher crop growth, and higher values of yield attributes of wheat. Similar results were obtained by Brar and Walia (2007). Among the weed control treatments, sulfosulfuron being on par with isoproturon + 2,4-D resulted in significantly taller plants and higher yield attributes as compared to metribuzin, weedy check and farmers practice.

The ZT registered 4.83% higher grain yield as compared to CT (Table 5). This reduction in grain yield in CT was due to poor crop growth and lower values of yield attributes owing to higher weed competition. All herbicides were on par with each other but produced significantly higher grain yield over weedy check during both the years. Interaction between tillage and weed control revealed (data not given) that application of sulfosulfuron produced the highest grain yield (3.83 t/ha) with CT in 2005-06 and with ZT (3.64 t/ha) in 2006-07. Irrespective of tillage, sulfosulfuron produced the highest grain yield (3.65 t/ha mean yield) followed by isoproturon + 2,4-D (3.5 t/ha). This could be attributed to efficient control of weeds by sulfosulfuron as evidenced by lowest density and dry weight of weeds and higher weed suppression efficiency (Table 4). It is further revealed that all herbicides produced higher yield when applied in ZT during both years except sulfosulfuron which gave higher yield in CT (2005-06).

Economics and energetics

The net income and B:C ratio were higher with ZT owing to higher yield, and less cost of cultivation. Irrespective of tillage practices, net income, and B:C ratio were highest (Rs 17,115/ha and 2.59) with isoproturon + 2,4-D followed by sulfosulfuron mainly due to lower cost of cultivation.

CT consumed 23.66% more energy as compared to ZT owing to more number of tillage operations. However, energy use efficiency and energy productivity being highest with ZT as compared to CT which was mainly due to higher energy output and lower energy input with ZT. Similar results have been reported by Jain *et al.* (2007) and Sharma *et al.* (2008).

Weedy check, and farmers practice showed significantly lower values of energy use efficiency and energy productivity as compared to rest of the weed control treatments. This was because of lower yield and higher energy input with above treatments. Among the herbicides, isoproturon + 2,4-D consumed the higher energy followed by sulfosulfuron. The lowest energy input was registered with metribuzin. The energy output, energy use efficiency and energy productivity was highest with sulfosulfuron followed by isoproturon + 2,4-D owing to higher yield and comparatively less energy input.

It is concluded that zero tillage wheat sowing and application of isoproturon + 2,4-D (0.75+0.6 kg/ha) or sulfosulfuron (0.25 kg/ha) at 35 days after sowing provides higher yield, benefit and higher energy productivity under late sown condition.

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