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Seed rate and weed management on yield and nutrient uptake of wheat (*Triticum aestivum*)*

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During the post-green revolution period, the productivity of wheat(*Triticum aestivum* L. emend. Fiori and Paol.) has increased tremendously but is still far below the potential yield (11.2 tonnes/ha) (Singh *et al.* 2010). Of the several constraints to low productivity of wheat, weeds have been recognized as an important one, which compete with crop plants for nutrients and other growth factors, and in absence of an effective control measure weeds remove considerable quantity of applied nutrients resulting in higher loss in yield. Jain *et al.* (2007) found that nitrogen, phosphorus and potassium uptake by the crop was 67.07, 65.97 and 64.97%, respectively less when the weed are allow to grow throughout the crop growing season compared with the treated plots. Weed infestation during the crop period causes more than 43.63% reduction in grain yield, depending on the weed densities and type of weed flora present (Verma *et al*. 2008). Weeds in wheat are generally controlled with manual and cultural manipulations. Now-a-days, herbicide use for weed control in wheat is becoming increasingly popular. However, due to indiscriminate use of herbicides in wheat there are chances of shift in weed flora and development of resistance. Technologies like use of natural herbicides and cultural practices such as higher seed rate, mechanical weeding, mulching etc. as a component of integrated weed management programme play a significant role in weed suppression, besides being economical and eco-friendly. Studies have shown that in ecological farming, it is possible to control weeds effectively by applying mechanical weeding and mulching during wheat growing season (Chakraborty *et al.* 2008, Sharma *et al.* 2010). Recently, use of medicinal plants like *neem* (*Azadirachta indicia* A. Juss.) and cat mint (*Anisomeles indica*) and their products as natural herbicides have been suggested as a viable options for alternative weed management in wheat under sustainable agriculture (Sindhu *et al*. 2005, Batish *et al*. 2007). Thus to make an effective weed management strategy, there is need to evaluate all the recent available options of weed control in wheat crop. In wheat, variable seed rate used in different parts of India ranges from 50 to 150 kg/ha depending on varying seed size, time and method of sowing. In recent years, conservation tillage practices viz zero tillage or bed planting system are gaining importance in Indo-Gangetic plains of India, as this practices reduces the incidence of *Phalaris minor* (Saini and Walia 2010) and requirement of seed rate up to 25% (Deshmukh 2007). In general, a high seed rate is required to secure an optimum and effective plant population for better yield and it is also expected to reduce weed growth. In fact, studies showed that weeds population and dry matter are supposed to be suppressed substantially through increasing plant populations (Olsen *et al.* 2006). Before increasing seed rates to enhance weed suppression in wheat, the economic benefit of higher seed rates should also be considered. Thus, seed rate plays a crucial role in improving productivity and profitability of the crop. However, studies exploring the possibility of weed management by using seed rate on wheat under zero till condition in eastern region of Uttar Pradesh to develop a holistic weed management strategy throughout cropping period, which is sustainable in terms of enhanced productivity without eroding the resource base, are lacking, though weeds population and dry matter was lesser reported in rice by applying higher seed rates (Gill 2008). Keeping this in view, the present study was made to assess the impact of seed rate and weed management treatments on the performance of wheat crop.

The field experiment was conducted during winter (*rabi*) season of 2005–06 and 2006–07 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (25° 18´– N latitude, 83° 03´– E longitude and altitude of 129 m above mean sea level). The soil of experimental site is sandy clay loam, slightly alkaline (*p*H

*Short note

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7.6) in reaction and moderately fertile being low in organic carbon (0.36%) and available nitrogen (185.20 kg N/ha) and medium in available phosphorus (19.75 kg P/ha) and potassium (208.56 kg K/ha). The experiment had 20 treatment combinations of four seed rates (75, 100, 125 and 150 kg/ha) and five weed management practices (mechanical weeding with *kudal* carried out twice at 15 and 30 days after sowing (DAS), rice straw mulch @ 2 tonnes/ha applied after sowing, neem oil spray (3%), sulfosulfuron (25 g/ha) and weedy check). These were evaluated under split-plot design, allocating seed rates to main plots and weed management practices to sub-plots with three replications. Spraying of neem oil and sulfosulfuron was done at 30 days after sowing (DAS) using knapsack sprayer with spray volume of 600 liters/ha. In mechanical weeding, weeds were removed with the help of *kudal*, a local sharp pointed tip hand hoe used for intercultural operations. Rice straw mulch was spread immediately after the sowing of crop. Wheat HUW 234 was sown with the help of zero till drill on 19 December 2005 and 2 December 2006 at a row spacing of 22.5 cm apart and harvested on 18 and 15April in the first and second respective seasons. An uniform basal dose of 60 kg N, 26.2 kg P and 49.8 kg K/ha were applied in the soil 2–3 cm below the seed of the crop and remaining 60 kg N was top dressed into two splits in two equal slits, each at after first irrigation and boot stage. Population and dry matter accumulation of weeds was recorded with the help of quadrate (0.25 m^2) from three places of border row on either side of each plot at 60 DAS and subjected to square-root transformation before statistical analysis. Weeds were cut at ground level, washed with tap water, sun-dried, dried in oven at 65 ^oC for 48 hr and then weighed. In weed management treatments, weed control efficiency was calculated over weedy check and in seed rate, it was calculated over the lowest seed rate of 75 kg seed/ha, on the basis of dry matter accumulation of weeds. Available nitrogen, phosphorus and potassium contents in initial soil were determined by alkaline potassium permanganate method, Olsen method and flame photometrically, respectively (Jackson 1973). Nitrogen, phosphorus and potassium contents of weed materials at 60 DAS and wheat (grain and straw) samples at the time of harvesting were estimated by modified microkjeldahl, vanadomolybdate phosphoric acid yellow colour and flame photometer methods, respectively (Jackson 1973). The percentage content was then multiplied by the total biomass produced for estimation of nutrient uptake (kg/ha). The economics was calculated on the basis of common cost of cultivation ₹ 14 126/ha in first year and ₹ 16 012/ha in second year, and selling prices of wheat grain 8.50/kg in both years and straw ₹ 2.00/kg in first year and ₹ 2.50/kg in second year.

The prominent weed species in the experimental field consisted of little seed canary grass (*Phalaris minor* Retz.), purple nutsedge (*Cyperus rotundus* L.), sorrel (*Rumex dentatus* L.), scarlet pimpernel (*Anagallis arvensis* L.) and common lambsquarters (*Chenopodium album* L.).

The population and dry matter accumulation of weeds were significantly influenced by different seed rates during both the years (Table 1). Weed population was significantly lower in crop sown at higher seed rates of 150 kg and 125 kg/ha as compared to recommended seed rate of 100 kg seed/ha and lowest seed rate of 75 kg seed/ha, though the differences between higher seed rates of 150 kg/ha and 125 kg/ha were statistically at par with each other. Increased plant density per unit area achieved by higher seed rates probably caused smothering of weeds and consequently reduced their dry matter. Further, successive increments of seed rate from 75 to 150 kg/ha significantly reduced dry matter accumulation of weeds. Seed rate of 150 kg/ha reduced 6.5, 13.6 and 30.3% in the first year and 3.2, 8.2 and 19.4% in the second year, dry matter of weeds compared to 125, 100 and 75 kg seeds/ha, respectively. Gill (2008) also observed that seed rate influenced the weeds dry matter effectively as the seed rates increased, the competition among crops increased which shows excellent smothering effect. Similarly, maximum weed control efficiency under 150 kg/ha seed rate and minimum under 75 kg/ha seed rate were recorded. Further, all the seed rates differed significantly among themselves on nutrients, viz. nitrogen, phosphorus and potassium (NPK) uptake by weeds (Table 1). Use of higher seed rates effectively decreased the uptake of NPK by weeds and significantly lowest uptake of NPK by weeds (6.6, 1.4 and 8.0 kg/ha in 2005–06 and 5.6, 1.2 and 6.3 kg/ha in 2006–07 N, P and K, respectively) was recorded with 150 kg seed/ha compared with highest NPK uptake by weeds (7.9, 1.7 and 9.6 kg/ha in 2005–06 and 6.9, 1.6 and 7.8 kg/ha in 2006–07 N, P and K, respectively) at 75 kg seed/ha.

The effect of seed rates on yield attributes, viz grains/spike and 1 000-grain weight did not vary significant in the first year but was significant in the second year (Table 2). Grains/spike and 1000-grain weight were decreased with increase in seed rates from 75 to 150 kg/ha**.** More grains/spike at lower seed rates was due to less competition among the plants for light, moisture and nutrients compared with those at higher seed rates. The mutual competition among plants at higher seed rates decreased the grains/spike and 1000-grain weight. Variation in seed rates significantly influenced the grain yield and straw yield of wheat and recorded the highest value (3.84 and 3.96 tonnes/ha wheat grain yield, and 5.46 and 5.59 tonnes/ha wheat straw yield in the first and second years, respectively) at 125 kg seed/ha which was at par with 100 kg seed/ha, but was significantly superior to rest of the seed rates (Table 2). Deshmukh *et al*. (2007) reported that grain yield was significantly higher due to the application of 100 kg/ha seed rate, but it was at par with the use of 75 kg/ha seed rate under bed planting system of wheat. On an average, seed rate of 125 kg/ha gave 4.0% more wheat grain yield than 100 kg seed/ha (3.75 tonnes/ha), which in turn recorded 20.0% and 26.0% more grain yield

Table 1 Effect of seed rate and weed management practices on weed indices

Treatment	Weeds population/m^2		Weed dry matter (g/m^2)		Weed control efficiency (%)		Nutrient uptake (kg/ha) by weeds					
							Nitrogen		Phosphorus		Potassium	
	2005–06	2005–06	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07
Seed rate (kg/ha)												
75 kg/ha	13.22 (174.27)	12.61 (158.51)	6.33 (39.53)	6.16 (35.50)	00.00	00.00	7.9	6.9	1.7	1.6	9.6	7.8
100 kg/ha	12.59 (158.01)	12.20 (148.34)	6.15 (37.33)	5.72 (32.17)	5.57	9.38	7.5	6.5	1.6	1.4	9.1	7.4
125 kg/ha	10.21 (103.74)	9.70 (93.59)	5.96 (35.00)	5.58 (30.69)	11.46	13.55	7.0	6.0	1.5	1.3	8.5	7.2
150 kg/ha	9.93 (98.10)	9.40 (87.86)	5.78 (32.86)	5.50 (29.73)	16.88	16.26	6.6	5.6	1.4	1.2	8.0	6.3
SEm±	0.21	0.19	0.28	0.11			0.12	0.10	0.02	0.02	0.15	0.07
CD (*P*=0.05)	0.70	0.64	0.96	0.38			0.43	0.36	0.09	0.07	0.52	0.23
Weed management practice												
Mechanical weeding 15 and 30 DAS	8.32 (68.72)	7.86 (61.28)	4.24 (17.50)	4.40 (18.88)	75.66	73.84	3.6	5.1	0.8	1.0	4.3	6.2
Rice straw mulch (2 tonnes/ha) after sowing	9.45 (88.80)	9.06 (17.62)	5.89 (34.25)	4.77 (22.27)	52.38	69.15	6.9	5.2	1.5	1.1	8.3	6.2
Neem oil spray (3%) 30 DAS	11.18 (124.49)	10.89 (118.09)	6.32 (39.41)	5.13 (25.80)	45.20	64.25	7.8	5.3	1.7	1.2	9.6	6.3
Sulfosulfuron (25 g/ha) 30 DAS	8.47 (71.24)	7.98 (63.18)	4.28 (17.83)	4.50 (19.75)	75.21	72.63	3.5	5.0	0.8	1.0	4.3	6.1
Weedy check	18.31 (334.47)	17.50 (305.75)	8.51 (71.91)	8.52 (72.16)	00.00	00.00	14.4	10.7	2.9	2.6	17.5	11.1
SEm±	0.17	0.14	0.25	0.07			0.12	0.09	0.02	0.02	0.15	0.07
CD (*P*=0.05)	0. 49	0.42	0.73	0.21			0.36	0.24	0.07	0.05	0.44	0.19

Figures in parentheses indicate original value

than 75 and 150 kg seeds/ha, respectively. However, Sandhu *et al.* (2010) observed that increasing trend in grain yield of wheat with increasing in seed rates. Selection of appropriate plant density for higher productivity depends mainly on tillering and lodging. High plant density beyond optimum leads to mutual competition among plants due to which it fails to exploit the inputs fully. A little lodging and mutual competition among plants at 150 kg seed/ha decreased yield of wheat. Net returns and benefit:cost ratio increased with increasing seed rates upto 125 kg/ha which recorded the highest net return (₹ 28 060/ha in 2005–06 and ₹ 30 249/ha in 2006–07) and benefit: cost ratio (1.81 in 2005–06 and 1.73 in 2006–07). Further, increasing in seed rates from 125 to 150 kg/ha caused reduction in net return and benefit: cost ratio owing to higher cost of seed and lower yield (Table 2). Similarly, there was also proportionate increase in the uptake of NPK in grain and straw with increase in seed rates from 75 to 125 kg/ha but it was decreased thereafter (Table 3). Low uptake of these nutrients under lower rates of seed may be attributed to less plant biomass (grain and straw). The uptake of nutrient is directly related to the yield of crop but their content on dry weight basis decreases with increase of seed rates.

Weed management practices significantly reduced the population and dry matter accumulation of weeds as compared to weedy check (Table 1). Mechanical weeding twice at 15 and 30 days after sowing was the most effective in reducing weed population and dry matter accumulation of weeds compared with other weed management treatments, due to proper control of weeds up to 30 days after sowing, thereafter the emergence of new flushes of weeds could not attain full growth under the shade of crop plants. Sulfosulfuron (25 g/ha) also reduced population and dry matter of weeds than rice straw mulching and neem oil spray. Verma *et al.* (2008) observed that sulfosulfuron (25 g/ha) application caused significant reduction in population and dry matter of weeds than other weed control treatments. Higher population and dry matter of weeds under rice straw mulching applied immediately after sowing compared to neem oil spray, might be due to re-growth and resurgence of seasonal weeds in new

Table 2 Effect of seed rate and weed management practices on yield and economics of wheat

Treatment	Grains/spike		1000-grain weight (g)		Grain yield (tonnes/ha)		Straw yield (tonnes/ha)		Net returns (₹/ha)		Benefit : cost ratio	
	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07
Seed rate (kg/ha)												
75 kg/ha	39.7	38.1	36.9	38.7	3.22	3.28	5.07	5.08	22 560	23 744	1.51	1.41
100 kg/ha	39.7	37.5	36.6	37.9	3.69	3.81	5.35	5.51	26 840	29 049	1.76	1.69
125 kg/ha	39.2	35.6	35.4	36.6	3.84	3.96	5.46	5.59	28 060	30 249	1.81	1.73
150 kg/ha	36.8	34.5	34.9	34.7	2.92	3.27	4.71	4.89	18 465	22 359	1.17	1.26
SEm±	0.8	0.7	0.6	0.7	0.09	0.08	0.14	0.11				
CD (*P*=0.05)	NS	2.4	NS	2.5	0.30	0.26	0.38	0.37				
Weed management practice												
Mechanical weeding 15 and 30 DAS	40.2	37.8	37.6	38.6	3.86	4.18	5.40	5.78	26 645	30 369	1.55	1.50
Rice straw mulch (2 tonnes/ha) after sowing	39.4	36.6	36.8	37.2	3.40	3.67	5.10	5.48	22 425	26 164	1.33	1.39
Neem oil spray (3%) 30 DAS	38.1	35.8	37.5	35.8	3.20	3.04	5.01	4.71	22 770	21 119	1.56	1.28
Sulfosulfuron (25 g/ha) 30 DAS	39.9	37.3	37.4	37.6	3.79	4.14	5.40	5.75	27 620	32 224	1.79	1.85
Weedy check	36.6	34.6	32.5	35.6	2.85	2.88	4.80	4.63	19 740	20 044	1.39	1.25
SEm±	0.8	0.7	0.7	0.7	0.08	0.08	0.13	0.11				
CD (*P*=0.05)	NS	2.1	NS	2.1	0.24	0.22	0.35	0.31				

NS, Non-significant

Table 3 Effect of seed rate and weed management practices on NPK uptake by grain and straw of wheat

Treatment	Nitrogen uptake (kg/ha)				Phosphorus uptake (kg/ha)				Potassium uptake (kg/ha)			
	Grain		Straw		Grain		Straw		Grain		Straw	
	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07
Seed rate (kg/ha)												
75 kg/ha	71.94	77.10	31.32	32.56	11.43	12.19	8.12	7.43	26.12	25.38	73.95	71.11
100 kg/ha	83.89	78.90	35.24	33.80	13.48	12.98	8.83	8.20	28.25	26.07	75.64	72.68
125 kg/ha	87.05	81.19	35.79	35.49	15.04	14.39	9.51	8.71	32.84	26.98	79.08	74.57
150 kg/ha	72.23	80.37	32.50	34.89	14.49	13.89	9.36	8.48	31.65	26.60	76.85	73.57
SEm±	1.69	0.12	0.68	0.15	0.29	0.19	0.20	0.19	0.35	0.13	0.40	0.21
CD (*P*=0.05)	5.85	0.40	2.37	0.53	1.01	0.66	0.68	0.67	1.21	0.45	1.37	0.74
Weed management practice												
Mechanical weeding 15 and 30 DAS	92.03	84.33	36.95	36.59	15.90	14.26	9.81	9.23	32.72	28.81	83.71	76.83
Rice straw mulch (2 tonnes/ha) after sowing	80.67	81.73	35.09	35.18	13.93	13.82	9.32	8.60	30.43	27.04	79.50	74.11
Neem oil spray (3 %) 30 DAS	66.83	76.77	30.13	32.90	11.54	13.55	8.00	8.23	25.21	24.46	68.26	71.47
Sulfosulfuron (25 g/ha) 30 DAS	91.12	83.58	36.77	36.47	15.74	14.03	9.77	8.90	34.38	28.38	83.31	76.09
Weedy check	63.25	70.53	29.63	29.79	10.93	11.16	7.87	6.07	23.86	26.26	67.12	66.33
SEm±	1.69	0.12	0.69	0.09	0.29	0.06	0.18	0.04	0.64	0.06	1.56	0.10
CD (*P*=0.05)	4.87	0.34	1.98	0.26	0.84	0.17	0.53	0.12	1.84	0.20	4.49	0.28

flushes after irrigation which was not successfully managed by this treatment. The maximum population and dry matter of weeds were recorded with the spraying of neem oil at 30 DAS because at that time negligible presence of some seasonal weeds like wild amaranthus (*Amaranthus viridis*) and congress grass (*Parthenium hysterophorus*) were in the experimental field which was effectively controlled by this treatment (Sindhu *et al.* 2005) as both these weeds were caused problem in successful wheat cultivation in the region in past. All the weed management practices increased the weed control efficiency over weedy check and its highest value (75.66% in 2005–06 and 73.84% in 2006–07) was observed with mechanical weeding followed by sulfosulfuron, rice straw mulching and neem oil spray, respectively (Table 1). Further, significant reduction in the uptake of NPK by weeds was recorded due to various weed management practices compared with that of weedy check (Table 1). Among weed management treatments, sulfosulfuron application at 30 DAS recorded the maximum and significantly higher reduction in the uptake of NPK by weeds which was 66.1, 96.7 and 63.6% higher in minimizing nitrogen, phosphorus and potassium loss compared to weedy check, respectively. Reduction in dry matter of weeds might be the reason for lower nutrients loss under this treatment. Results have conformity with the finding of Verma *et al.* (2008).

Weed management practices significantly influenced yield attributes of wheat in the second year only (Table 2). Mechanical weeding twice being at par with sulfosulfuron 25 g/ha and rice straw mulch recorded significantly higher grains/spike and 1000-grain weight compared to neem oil treated plots except in grains/spike. Due to stiff competition from weeds the yield attributes was recorded the least in the weedy check plots. Weed management practices resulted in significant increase in grain yield and straw yield of wheat as compared with weedy check (Table 2). Among weed management practices, mechanical weeding at 15 and 30 DAS resulted in significantly higher grain yield than rest of the weed control measures. Hence, the highest increase in grain yield up to 35.4 and 45.1% was recorded under mechanical weeding, followed by sulfosulfuron (33.0 and 43.8%), rice straw mulch (19.3 and 27.4%) and neem oil (12.3 and 5.6%) treatments in the first and second years, respectively over the weedy check. Similar trend was noted in straw yield also under each treatment. The higher wheat grain yield and straw yield under weed management practices may be due to marked decrease in dry matter of weeds and thereby better crop growth and yield attributes. These facts have conformity with the finding of Pandey *et al.* (2006). However, Sharma *et al.* (2010) reported that chemical weeding was significantly superior to mechanical weeding for increasing the growth and yield attributes which led to an increase in grain yield and straw yield of wheat. All weed management practices gave higher net returns and benefit: cost ratio than weedy check (Table 2). Lower grain yield and straw yield due to severe crop-weed competition throughout the crop season in weedy check plots could be the reason for decrease in net return. Among weed management practices, the post-emergence application of sulfosulfuron at 25g/ha was found more remunerative, as it fetched the highest net return (₹ 27 620/ha in 2005–06 and ₹ 32 224/ha in 2006–06) and benefit: cost ratio (1.79 in 2005–06 and 1.85 in 2006–07) compared with other weed control measures. The higher cost of weed management is the reason for lower value of net return (₹ 26 645/ha in 2005–06 and ₹ 30 369/ha in 2006–07) under mechanical weeding treatment in spite of the highest grain and straw yields. Kumar *et al.* (2010) also reported that lower cost of cultivation and competitive yield in herbicide application resulted in more net returns than mechanical weeding. In addition, weed management practices also significantly increased the NPK uptake in grain and straw than weedy check (Table 3). The best weed management practices, viz mechanical weeding twice at 15 and 30 DAS and sulfosulfuron 25 g/ha at 30 DAS being on par recorded significantly higher NPK uptake in grain and straw of wheat compared to rest of the weed management treatments. Increase in NPK uptake by crop under mechanical weeding twice at 15 and 30 DAS and sulfosulfuron at 30 DAS was due to effective control of weeds resulted in higher total plant biomass production and hence, higher uptake in grain and straw (Pandey *et al.* 2006).

Thus, it can be concluded that sowing at 125 kg seed/ha with post-emergence application of sulfosulfuron @ 25 g/ha at 30 DAS is the most economical and efficient weed management practice for achieving high yield in wheat.

SUMMARY

A field experiment was conducted to assess the influence of seed rates and weed management practices on weed growth, yield and nutrients uptake of wheat. The treatments comprised of all possible combinations of four seed rates (75, 100, 125 and 150 kg/ha) and five weed management practices (mechanical weeding twice, rice straw mulch @ 2 tonnes/ha, neem oil spray (3%), sulfosulfuron (25 g/ha) and weedy check). Increasing seed rates from 75 to 150 kg/ha significantly decreased dry matter of weeds in wheat. On an average, use of 125 kg/ha seed rate being at par with 100 kg seed/ha, gave significantly 20 and 26 % higher grain yield than 75 and 150 kg seeds/ha, respectively. Maximum net return, benefit: cost ratio and NPK uptake by wheat was obtained at 125 kg seed/ha. Among weed management practices, mechanical weeding twice at 15 and 30 DAS proved the most effective treatment in reducing weeds dry matter which was at par with sulfosulfuron 25 g/ha, and gave significantly higher grain yield and NPK uptake by wheat than weedy check.

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