Indian Journal of Agronomy **64** (3): 354–359 (September 2019)

Research Paper

Productivity and profitability of wheat (*Triticum aestivum*) as influenced by weed and nitrogen management under semi-arid conditions

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Received : February 2019; Revised accepted : July 2019

ABSTRACT

A field experiment was conducted during the winter (*rabi*) season of 2016–17 and 2017–18 at Agronomy research farm, Jobner, Rajasthan, to assess the effect of weed-management practices and nitrogen fertilization on productivity and profitability of wheat (*Triticum aestivum* L.). Pooled results indicated that, 2 hand-weeding treatment (HW)–25 and 45 days after sowing (DAS)–was the most superior treatment in reducing the weed dry matter and weed count, and significantly improved the growth and yield-attributing characters of wheat and net returns. This treatment was closely accompanied by mesosulfuron 3% + iodosulfuron 0.6% @ 14.4 g/ha. Among weed-management practices, the highest grain and straw yields (4.65 t/ha and 5.72 t/ha) were obtained with 2 hand-weeding treatment. However, post-emergence application of mesosulfuron 3% + iodosulfuron 0.6% @ 14.4 g/ha was the most superior and equally effective herbicidal treatment (4.46 t/ha and 5.24 t/ha). Nitrogen fertilization at 90 kg/ha significantly improved the growth and yield attributes as well as yield of wheat over preceding levels. However, it remained at par with 135 kg N/ha.

Key words: Hand-weeding, Mesosulfuron 3% + iodosulfuron, Nitrogen fertilization, Wheat

Wheat is one of the most important crops of India not only in terms of acreage but also in terms of its versatility for adoption under wide range of agro-climatic conditions and crop-growing situations. In India, it is cultivated on 30.42 million ha with 98.38 million tonnes production (DES, 2016–17). Heavy weed infestation is a major recognized bottleneck in realizing the yield potential of wheat. The weed competition became serious in wheat-growing areas with the introduction and large area adoption of high-yielding dwarf varieties in India. Wheat is generally infested with diverse kind of weed flora including broad and narrow leaf weeds. It results in 20–40% average reduction in grain yield (Kumar *et al.*, 2010)

Mechanical methods of weed control are efficient but in view of scanty availability of labour and ever-increasing wages and closer row spacing of wheat, manual weed control has become cumbersome, labour intensive, time-consuming and costly. Therefore, it is essential to search effective herbicide and herbicide mixtures which can take care of diverse kind of weed flora in wheat. There has been a growing concern about depletion of the available pool of nitrogen, particularly in light-textured soils with low organic matter. Nitrogen is a universally deficient plant nutrient in most of the Indian soils, particularly the light textured ones of semi-arid regions of Rajasthan, where major area of wheat cultivation is confined (Chhonkar and Rattan, 2000). In India, nutrient-use efficiency is very low because of improper dose, time and method of fertilizer application, inadequate soil-moisture status, weed infestation, weed-crop competition is of supreme importance. The weed can deprive the crop of about 47% nitrogen, 42% phosphorus and 50% potash through their nutrient uptake (Kumar and Singh, 1998). Thus, optimum quantity of nutrient and proper weed management is of paramount importance to productivity and nitrogen-use efficiency of wheat. Hence, an experiment was conducted on these aspects.

MATERIALS AND METHODS

The field experiment was conducted during the winter

Based on a part of Ph.D. thesis of first author, submitted to Sri Karan Narendra Agriculture University, Jobner, Rajasthan in 2018 (unpublished)

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(*rabi*) season of 2016–17 and 2017–18 at Sri Karan Narendra Agriculture University, Jobner (27°05'N; 75°28'E, above mean sea-level), Jaipur, Rajasthan. The soil was loamy sand, having low organic carbon (0.21%) and available N (128.6 kg/ha), medium P (15.4 kg/ha) and K (148.6 kg/ha) and was slightly alkaline (*p*H 8.2). The experiment was laid out in a split-plot design with 3 replications. The main plot comprised 7 weed-control treatments [weedy check, 1 hand-weeding (HW) 25 days after sowing (DAS), 2 HW at 25 and 45 DAS, 2,4-D ester @ 0.5 kg/ha, metsulfuron methyl @ 4 g/ha, sulfosulfuran 75% + metsulfuran methyl 5 WG @ 40 g/ha, mesosulfuron 3% + iodosulfuron 0.6% @ 14.4 g/ha applied 25–30 DAS, and 4 nitrogen levels (0, 45, 90 and 135 kg/ha) were taken as subplots. Wheat variety 'Raj 4120' was sown with standard package of practices. Six irrigations were applied to the crop. Rainfall received during the crop-growing season was 24.8 mm and 5.6 mm during 2016–17 and 2017–18 respectively. Post-emergence application of herbicides was done 25–30 DAS as per treatments. A foot sprayer was used for spraying the herbicides using a spray volume of 700 litres water/ha. In the plots ear marked for hand-weeding, the operation was done 25 and 45 DAS with the help of *kassi* as per treatment. Nitrogen was applied through urea as per treatments in 2 equal splits, i.e. half basal at the time of sowing and remaining half top-dressed at the time of first irrigation and full dose of P was applied at time of sowing. Sowing was done with 'Pora' method in rows, spaced at 22.5 cm with average depth of 4 cm using seed rate of 100 kg/ha. After leaving 2 rows on each side as well as 50 cm along the width of each side, a net plot area of 3 m × 1.35 m was harvested separately for recording the yield attributes and yield. The harvested material was threshed after the sun-drying. Wheat grains were cleaned by winnower and yield was recorded. Straw yield was obtained by subtracting grain yield from total biomass yield and expressed in t/ha. Harvest index was calculated by dividing economic yield with biological yield and expressed in percentage. Observations on weeds were recorded with the help of a quadrate (0.5 m × 0.5 m) placed randomly at 2 spots in each plot. Data on weeds were subjected to square-root transformation ($\sqrt{x+0.5}$) to normalize their distribution. Net returns were calculated based on grain and straw yield and prevailing market price of wheat grain. Nitrogen content in grain and straw yield was determined by standard method. Accumulation of nitrogen in wheat grain and straw was calculated by multiplying the dry-matter yield with their content. The experimental data recorded were subjected to statistical analysis in accordance with the Analysis of variance technique as suggested by Fisher (1950). Significance of differences among treatment effects was tested by 'F' test as described by Panse and Sukhatme (1985) for split-plot design experiments.

RESULTS AND DISCUSSION

Weed and crop growth

Pooled results (Table 1) revealed that at harvesting stage, 2 HW done 25 and 45 DAS was the most effective treatment, recording significantly lowest weed dry matter and weed count (Table 1). Remaining at par with metsulfuron 3% + iodosulfuron 0.6% @ 14.4 g/ha, the treatment reduced the weed biomass by huge margin of 37.3, 58.8, 74.8, 79.5 and 1370.0 kg/ha and weed count by 30.4, 36.9, 46.0, 46.6 and 95.8% at harvesting in comparison to sulfosulfuron 75% + metsulfuron methyl 5 WG @ 40 g/ha, 1 HW at 25 DAS, metsulfuron methyl @ 4 g/ha, 2,4-D ester @ 0.5 kg/ha and weedy check treatments, respectively. Pooled results further showed that the highest weed-control efficiency at harvesting was recorded with 2 hand-weedings treatment which was significantly higher than rest of the treatments. Mesosulfuron 3% + iodosulfuron 0.6% @ 14.4 g/ha and sulfosulfuron 75% + metsulfuron methyl 5 WG @ 40 g/ha controlled the weeds to the extent of 88.72 and 87.45% at harvesting stage, respectively, and thus found to be the next better and statistically similar herbicidal weed-control treatments. Different levels of nitrogen fertilization could not bring variation in weed-control efficiency at any stage of crop growth up to the level of significance (Table 1).

The weed-control treatments significantly influenced the plant height, total number of tillers/plant and dry-matter accumulation (DMA). All the weed-control treatments, i.e. hand-weeding and herbicide application significantly influenced the growth parameters of the crop as compared to weedy check plot (Table 1). Two hand weedings done at 25 and 45 DAS resulted in the highest plant height during all the stages with 27.4% higher plant height than the weedy check at harvesting stage, and also recorded the highest crop dry matter of 1,075.4 g/m^2 at harvesting stage with a remarkable increase of 8.4, 14.1, 20.8, 23.0 and 54.4% at harvesting over sulfosulfuron 75% + metsulfuron methyl 5 WG @ 40 g/ha, 1 HW at 25 DAS, metsulfuron methyl @ 4 g/ha, 2,4-D ester @ 0.5 kg/ha and weedy check treatments, respectively. Being at par with sulfosulfuron 75% + metsulfuron methyl 5 WG @ 40 g/ha, metsulfuron methyl @ 4 g/ha and 2, 4-D ester @ 0.5 kg/ha, 1 HW at 25 DAS also registered significant enhancement (34.8%) at harvesting stage over weedy check treatments. Two hand-weedings done at 25 and 45 DAS and mesosulfuron 3% + iodosulfuron 0.6% @ 14.4 g/ha were the most superior and statistically similar treatments and recorded significantly higher number of total tillers/plant. Attaining the values of 11.18 and 10.87 at harvesting stage, these treatments recorded 54.6 and 50.3% increase in number of total tillers/plant, respectively, over weedy check. These treatments were closely accompanied by sulfosulfuron 75% + metsulfuron methyl 5 WG @ 40 g/ha, wherein 10.42 total number of tillers/plant were noted. The improvement in growth attributes under different weed-control treatments can mainly be ascribed to the reduced density and dry weight of weeds that resulted in increase in space, moisture, nutrients and light for crop plants. Mechanical weed control improved the physical condition of the soil by making it loose, porous and aerated that might have accelerated the establishment and proliferation of roots and ultimately the plant growth. Meena and Singh (2011) with hand-weeding twice and Brar and Walia (2010) with mesosulfuron 3%+ iodosulfuron 0.6% @ 14.4 g/ha reported significant increment in growth of wheat. Metsulfuron methyl @ 4 g/ha and 2,4-D ester @ 0.5 kg/ha registered 9.6 and 9.2%, 27.8 and 25.5% and 32.6 and 31.0% increase in plant height, crop dry-matter production and total number of tillers/ plant, respectively, over weedy check and thus were found as the least effective herbicidal treatment.

Perusal of data (Table 1) revealed that every increase in level of N significantly increased the dry-matter production of weed up to 135 kg/ha at harvesting stage of the crop over preceding levels. The maximum weed dry-matter and weed count at harvesting stage was obtained with 135 kg N/ha. The results showed that growth attributes were significantly influenced by nitrogen fertilization (Table 1). Application of 90 kg N/ha enhanced the plant height by 6.9 and 50.5%, dry-matter by 12.6 and 40.1% and total number of tillers by 7.1 and 51.1% at harvesting stage over 45 kg N/ha and control, respectively. Further increase in its N level to 135 kg/ha maximized the growth characters but the increase was not up to the level of significance. It was perhaps to better nutritional environment for plant growth at active vegetative stages as a result of improvement in root growth, cell hypertrophy and hyperlasia, in plant body. Our findings are in conformity with the results of Behera *et al.* (2015) and Satyanarayana *et al.* (2017).

Yield and yield attributes

Effective tillers/plant, grains/spike, spike length and 1,000-grain weight, grain and straw yield were significantly influenced by different weed-control treatments (Table 2). Two hand-weedings treatment provided the long-time weed control and hence, resulted in appreciably higher yields and yield attributes among all the treatments except mesosulfuron 3% + iodosulfuron 0.6% @ 14.4 g/ ha. Two hand-weedings done at 25 and 45 DAS increased the grain yield by 9.0, 14.5, 18.8, 20.2 and 38.7% over sulfosulfuron 75% + metsulfuron methyl 5 WG @ 40 g/ha, 1 HW at 25 DAS, metsulfuron-methyl at 4 g/ha, 2, 4-D

Table 1. Effect of weed management and nitrogen fertilization on growth and yield attributes of wheat (pooled data of 2 years)

Treatment	Weed count/0.25 m^2	Weed dry matter production (kg/ha) at harvest	Weed control efficiency (%)	Plant height at harvesting (cm)	DMA (g/m^2 row length) at harvest	Total tillers/ plant	Effective tillers/ plant	Spike length (cm)	Grains/ spike	1000-grain weight (g)
Weed control										
Weedy check	6.84 (46.85)	1521.5	-	71.8	696.6	7.23	3.42	7.59	32.64	39.77
1 HW at 25 DAS	1.89 (3.09)	210.3	86.04	82.3	939.1	9.94	4.84	10.97	39.39	42.64
2 HW at 25 and 45 DAS	1.56 (1.95)	151.5	90.03	91.5	1075.4	11.18	5.41	12.21	44.33	44.51
2,4-D ester @ 0.5 kg/ha	2.04 (3.65)	231.0	84.64	78.4	874.2	9.47	4.57	9.82	37.40	40.87
Metsulfuron methyl @ 4.0 g/a	2.03 (3.61)	226.3	84.97	78.6	890.2	9.59	4.60	10.15	38.09	41.36
Sulfosulfuron 75% + metsulfuron methyl 5 WG @ 40 g/ha	1.82 (2.80)	188.8	87.45	85.1	991.5	10.42	5.12	11.64	41.29	43.52
Mesosulfuron 3% + iodosulfuron 0.6% @ 14.4 g/ha	1.67 (2.29)	169.4	88.72	89.0	1030.1	10.87	5.26	11.92	43.08	44.58
SEm±	0.05	7.47	1.14	1.43	19.71	0.19	0.10	0.23	0.70	0.69
CD (P=0.05)	0.16	21.80	3.36	4.19	57.54	0.55	0.29	0.68	2.03	2.02
Nitrogen (kg/ha)										
0	2.36 (6.95)	325.8	85.43	60.3	730.4	7.17	3.47	7.96	28.82	39.34
45	2.54 (8.95)	369.9	87.24	84.8	908.9	10.08	4.87	10.83	40.55	42.13
90	2.60 (9.79)	408.8	87.47	90.8	1023.4	10.85	5.26	11.69	43.66	43.78
135	2.69 (11.01)	437.7	87.77	93.6	1049.6	11.15	5.37	11.97	44.81	44.61
SEm±	0.04	6.69	0.84	0.98	13.05	0.13	0.07	0.15	0.481	0.449
CD (P=0.05)	0.11	18.8	NS	2.76	36.72	0.36	0.19	0.41	1.35	1.36

HW, Hand-weeding; DAS, days after sowing; DMA, dry-matter accumulation ester at 0.5 kg/ha and weedy check treatments, respectively. Post-emergence application of sulfosulfuron 75% + metsulfuron methyl 5 WG @ 40 g/ha, followed by 1 HW done at 25 DAS were the next superior and equally effective treatments in enhancing yield of wheat. They also improved the grain yield by margin of 27.2 and 21.1% over weedy check. The corresponding increase in straw yield was 19.7 and 14.8% and biological yield was 23.0 and 17.5%. The treatments comprising metsulfuron-methyl at 4 g/ha, 2,4-D ester at 0.5 kg/ha also resulted in 16.8 and 15.3% higher grain yield and 10.0 and 9.6% higher straw yield over the weedy check but they were found inferior to above described treatments. Application of various weed-control measures kept the crop almost weed free up to 40–50 DAS, resulting in more moisture, nutrients and space for crop. It is apparent that under weed infested condition, the sink is not developed enough to accumulate the meaningful photosynthates translocating towards seed formation. Our results strongly support the findings of Chhipa *et al.* (2005), Katara *et al*. (2012) and Bhullar *et al.* (2012) in wheat. The lesser grain and straw yield with metsulfuron-methyl at 4 g/ha and 2, 4-D ester at 0.5 kg/ha may be attributed to their ability to control broad-leaf weeds only (Gupta, 2012). Use of single molecule is likely to suppress only one category in comparison to other premix herbicides. The inferiority of these two herbicides has also been reported by Meena and Singh (2011) and Patel *et al.* (2017) in wheat.

Yield attributes and yield also increased significantly with every increase in level of N up to 90 kg/ha (Table 2). As grain yield is primarily a function of cumulative effect of yield-attributing characters, the higher values of these attributes can also be assigned as the most probable reason for significantly higher grain yield. It is well evident from the positive correlation between yield and dry-matter accumulation of crop (Table 3). Jat *et al.* (2014) also documented significant and positive influence of nitrogen application on yield attributes and yield of wheat crop.

Economics

Significantly higher net returns and benefit: cost (B: C) ratio were obtained under different weed-control treatments owing to their higher yield in comparison to weedy check (Table 2). The highest net returns were recorded under 2 HW treatment (₹71.95 × 10^3/ha) with B : C ratio of 3.23, thus increasing it by 10^3 × 21.7 10^3/ha over weedy check. Among the herbicidal treatments, mesosulfuron 3% + iodosulfuron 0.6% @ 14.4 g/ha recorded significantly highest net returns and B: C ratio, followed by sulfosulfuron 75%+ metsulfuron methyl 5 WG @ 40 g/ha and 1 HW at 25 DAS. The treatments comprising metsulfuron-methyl at 4 g/ha and 2, 4-D ester at 0.5 kg/ha also recorded higher net returns and B : C ratio than weedy check. The higher net returns and B : C ratio recorded under these superior treatments can be explained easily with the corresponding higher grain yield. The maximum B: C ratio (3.52) under mesosulfuron 3% + iodosulfuron 0.6% @ 14.4 g/ha seems to be due to comparatively lower cost of treatment application. Results of the present investigation are in cognizance with the find-

Table 2. Effect of weed control options and nitrogen fertilization on production and profitability of wheat (pooled data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio
Weed control				
Weedy check	3.35	4.37	50.25	2.94
1 HW at 25 DAS	4.06	5.01	62.00	3.13
2 HW at 25 and 45 DAS	4.65	5.72	71.95	3.23
2, 4-D ester @ 0.5 kg/ha	3.86	4.79	59.22	3.14
Metsulfuron methyl @ 4.0 g/a	3.91	4.81	60.22	3.19
Sulfosulfuron 75% + metsulfuron methyl 5 WG @ 40 g/ha	4.26	5.23	66.78	3.32
Mesosulfuron 3% + iodosulfuron 0.6% @ 14.4 g/ha	4.46	5.43	71.48	3.52
SEm±	0.08	0.12	1.43	0.05
CD (P=0.05)	0.22	0.34	4.18	0.15
Nitrogen (kg/ha)				
0	3.18	3.69	42.91	2.55
45	4.15	5.19	65.23	3.32
90	4.47	5.59	71.78	3.50
135	4.51	5.73	72.58	3.48
SEm±	0.06	0.06	0.87	0.04
CD (P=0.05)	0.15	0.16	2.44	0.10

HW, Hand weeding; DAS, days after sowing

Table 3. Correlation coefficients (r) and regression equations for the relationship between grain yield (Y) growth and yield-attributing characters (X)

Parameter	2016–17		2017–18		Pooled	
	Correlation coefficient (r)	Regression equation $Y = a + b_y \times .X$	Correlation coefficient (r)	Regression equation $Y = a + b_y \times .X$	Correlation (r)	Regression $Y = a + b_y \times .X$
DMA at harvest (kg/ha)	0.935**	$Y = 0.611 + 0.0158\ X_4$	0.926**	$Y = 0.745 + 0.168\ X_5$	0.953**	$Y = 0.634 + 0.165\ X_5$
Number of effective tillers/plant	0.978**	$Y = 0.445 + 0.746\ X_6$	0.926**	$Y = 1.402 + 574.46\ X_6$	0.970**	$Y = 0.945 + 0.660\ X_6$
Number of grains/spike	0.995**	$Y = 0.195 + 0.965\ X_7$	0.913**	$Y = 0.987 + 0.795\ X_7$	0.976**	$Y = 0.581 + 0.088\ X_7$
Spike length (cm)	0.953**	$Y = 0.446 + 0.342\ X_8$	0.930**	$Y = 1.435 + 0.247\ X_8$	0.965**	$Y = 0.941 + 0.295\ X_8$
1,000-grain weight (g)	0.820**	$Y = -4.795 + 0.207\ X_9$	0.852**	$Y = -2.988 + 0.167\ X_9$	0.890**	$Y = -4.796 + 0.209\ X_9$

DMA, dry-matter accumulation; **P=0.01

ings of Patel *et al.* (2017) and Tiwari *et al.* (2017). Application of 90 kg N/ha also fetched additional net returns of 71.78×10^3/ha over preceding levels with B : C ratio of (Table 2), which is primarily owing to higher grain yield with comparatively lesser additional cost of N (Jat *et al.*, 2014). A strong positive correlation existed between grain yield of wheat and its yield-attributing characters (Table 3). Pooled results showed that every unit increase in crop dry matter at harvesting stage, effective tillers/plant, grains/spike, spike length and test weight of crop increased the grain yield of wheat by 16.47, 660.29, 88.61, 295.45 and 208.97 kg/ha, respectively in pooled analysis.

Thus, 2 hand-weedings done at 25 and 45 days after sowing and application of nitrogen at 90 kg/ha increased the growth, yield attributes and yield of wheat crop compared to the other treatments. Mesosulfuron 3% + iodosulfuron 0.6% @ 14.4 g/ha in combination with 90 kg N/ha proved the best herbicidal treatment in achieving higher monetary returns under semi arid eastern plan zone of Rajasthan.

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