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Research Paper

Effect of weed management options and nitrogen scheduling on weed dynamics and yield of wheat (*Triticum aestivum*) under Central Plain Zone of Uttar Pradesh

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) seasons of 2014–2015 and 2015–16 at Kanpur, Uttar Pradesh, to study the effect of weed-management options and nitrogen scheduling on weed dynamics and yield of wheat (*Triticum aestivum* L.). Common infesting weeds which appeared in wheat field were *Phalaris minor* Retz. and *Cynodon dactylon* (L.) Pers. among grasses, and *Chenopodium album* L., *Anagallis arvensis* L., *Melilotus alba* Medik. and *Convolvulus arvensis* L. as broad-leaf weeds. Moreover, among sedges, only 1 species, *Cyperus rotundus* L. was observed. Among the weed-management options, mesosulfuron-methyl + Iodosulfuron-methyl sodium (400 g/ha) with higher dose of nitrogen (150 kg N/ha) applied in 3 spilt applications [50% as basal + 25% at crown-root initation (CRI) + 25% at flowering] proved significantly superior in minimizing the density (33%) and biomass of weeds (34%) at 60 days after sowing (DAS). The former treatment increased the leaf-area index (LAI) and SPAD values that elevated the production of wheat grain yield. Among time of nitrogen application, 3 splits (50% as basal + 25% at CRI + 25% at flowering) enhanced the nutrient-uptake efficiency (27.4%) and total nutrient uptake (40.2%) by crop than 3 equal splits at sowing (basal), CRI and flowering. Higher dose of nitrogen (150 kg N/ha) resulted in higher yield (15.7%) and nutrient uptake (13.4%) than its lower dose. Thus, application of ready-mixed post-emergence herbicides, i.e. mesosulfuron + iodosulfuron (400 g/ha) with higher dose of nitrogen (150 kg N/ha) applied 50% as basal and 25% top-dressed at CRI and 25% at flowering was most effective with respect to weed-suppression, yield and economics of wheat.

Key words : Herbicide mixture, Leaf area index, SPAD value, N uptake efficiency

Wheat, being the most important cereal crop after rice in the country, contributes nearly one-third to total production. The introduction of high yielding dwarf varieties coupled with increased use of fertilizer and irrigation have increased weed problem which is one of the major constraints in achieving potential yield of wheat. Slow growth of wheat at early stages and application of more fertilizer as well as irrigation right from sowing, encourages the rapid growth of weeds and if not controlled, they cause loss in yields to the tune of 15 to 40% (Jat *et al*., 2003). The losses caused by weeds vary depending on the weed species, their abundance, crop management options and environmental factors, under extreme cases, losses can be complete crop failure (Malik and Singh, 1993). The high cost and less efficacy of manual weeding in wheat made chemical weed control popular. Since the wheat crop is infested by number of weed species, it gets difficult to control them with single herbicide having just one kind of mode of action. It also contributes to a shift towards difficult to control weeds and rapid evolution of multiple herbicide resistance which is a threat to wheat production (Singh, 2007). Hence, there is a need to use mixture of herbicides in a way to lower their load on environment and improve weed-control efficiency without any adverse effect on crop. Nitrogen (N) is a major nutrient required by crop plants for optimum vegetative and reproductive growth. Wheat has a high demand for nitrogen during grain filling. If this cannot be met by the soil N, premature senescence may occur as nitrogen is remobilized from the leaves to meet the requirements of the developing grains, resulting in a lower photosynthetic rate (Frederick and Camberato, 1995). Among major cereals, wheat requires 1 kg nitrogen to produce 44 kg grain (Pathak *et al*., 2003). Furthermore, Kim *et al*. (2006) reported a significant inter-

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action between herbicide and nitrogen, where increased nitrogen was found to enhance the performance of herbicides as well as nitrogen scheduling not only influences the crop growth but also influences weed density and biomass. Since very little information on the combined effect of weed-management options, nitrogen levels and its scheduling on wheat is present. Hence, present investigation was undertaken to study the effect of weed-management options, nitrogen levels and its time of application on weed-suppression and yield of wheat.

MATERIALS AND METHODS

A field experiment was conducted during the winter (*rabi*) seasons of 2014–15 and 2015–16 at Students' Instructional Farm of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (25°28' to 26°58' N and 79°31' to 80°34' E), Uttar Pradesh. The soil of the experimental field was sandy loam in texture with slightly alkaline in reaction (*p*H 7.70), low in organic carbon (0.33%), available nitrogen (254 kg N/ha), and medium in available phosphorus (12.0 kg P/ha) and potassium (156 kg K/ha). Treatments were laid down in a randomized complete block design, replicated thrice with 3 factors. First factor consisted of 3 weed-control options, viz. mesosulfuron - methyl + iodosulfuron - methyl sodium (400 g/ha), clodinafop propargyl + metsulfuron methyl (60 + 4 g/ha) and weedy check; the second and third factors comprised 2 nitrogen levels (120 kg N/ha and 150 kg N/ha) and 3 times of nitrogen application, viz, 50% as basal + 50% at crown-root initation (CRI), 50% as basal + 25% at CRI + 25% at flowering and 33.5% as basal + 33.5% at CRI + 33.0% at flowering, respectively. Wheat variety 'K 1006' was sown on 21 November, 2014 and 24 November, 2015 with 100 kg seed/ha, keeping row-to-row distance of 22.5 cm during both the years of experimentation. Nitrogen was applied as per treatment, but full amount of P and K were applied at the time of sowing. As per treatments, herbicides were dissolved in water and applied 30 days after sowing using knapsack sprayer fitted with flat-fan nozzle. Total weed density and biomass of weeds were recorded 60 days after sowing (DAS) and at harvesting using a quadrat of 0.5 m × 0.5 m randomly selected at 2 places in each plot. Furthermore, all weeds from quadrat were cut at the ground level, placed in a paper bag and dried for 48 hrs in an oven at 60°C and then were weighed to determine the weed dry biomass. Leaf-area index (LAI) is defined as the area of leaves/unit area of soil surface. The LAI was quantified with the Accu PAR model LP-80 (Decagon devices, Inc. instruments) which calculated the LAI based on the above and below canopy PAR measurement. Leaf-chlorophyll content was estimated non-destructively by measuring leaf greenness using a portable SPAD (Soil Plant Analysis Development)-502 chlorophyll meter. Grain yield recorded in kg/plot was finally converted into grain yield in kg/ha. Nitrogen-uptake efficiency (%) is the ratio of total plant N uptake to N supplies (Ortiz-Monasterio *et al*., 1997). Weed data (density and biomass) were subjected to square-root transformation $\sqrt{x+0.5}$. Weed-control efficiency was computed on the basis of total weed density at harvesting. All data were put to analysis of variance as described by Gomez and Gomez (1984). The mean assessment was accomplished by least significant difference (LSD) at 5% level of significance. Nutrient uptake in grain and straw of the crop was computed in kg/ha in relation to yield per ha by using the following formula:

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient (\%) in grain/straw} \times \text{grain/straw yield (kg/ha)}}{100}$$

RESULTS AND DISCUSSION

Weed flora

The major weed species appeared in experimental field were *Chenopodium album*, *Anagallis arvensis*, *Melilotus alba* and *Convolvulus arvensis* among broad-leaf weeds, and *Phalaris minor* and *Cynodon dactylon* among grasses. Moreover, among sedges, only 1 species, i.e. *Cyperus rotundus,* was observed. Weed-control treatments significantly reduced the density and biomass of total weeds than the weedy check. Ready-mixed formulation of Mesosulfuron-methyl + Iodosulfuron-methyl sodium (400 g/ha) proved the most effective herbicide combination against broad-leaf, grassy and sedges weeds and recorded significantly lower density and biomass of weeds as per 2 years pooled data (Table 1). The highest weed-control efficiency was also recorded under ready-mixed formulation of Mesosulfuron-methyl + Iodosulfuron-methyl sodium (400 g/ha) than tank mixture of Clodinafop propargyl + Metsulfuron methyl (60 + 4 g/ha). The higher efficiency of Mesosulfuron-methyl + Iodosulfuron-methyl sodium than tank mixer of Clodinafop Propargyl + Metsulfuron methyl can be attributed to its slow degradation in soil; it controls weeds up to 4–6 weeks crop-growth period. However, Clodinafop propargyl is quickly degraded in soil and has little or no soil activity and, therefore, grassy weeds emerging after application could not be controlled. The results confirm the findings of Punia *et al*. (2008). Higher dose of nitrogen, i.e. 150 kg/ha, significantly reduced the density and biomass of weeds as compared to lower rates of nitrogen i.e. 120 kg/ha. Here, it is necessary to mention that critical period of crop-weed competition in wheat is between 30 and 50 DAS (Chaudhary *et al*., 2008), which means those nitrogen rates which provide competitive advantage to crop vis-a-vis suppressive effect on weeds up to 50 DAS would have positive influence on crop yield. Besides above facts, experimental findings also showed that during the critical period of crop weed competition, application of higher dose of nitrogen (150 kg N/ha) shifted the competitive advantage in favour of crop and also helped in smothering the weeds. It appeared that vigorous crop stand and growth due to higher nitrogen level asserted a strong smothering effect on growth and development of weeds (Patel *et al*., 2012).

Out of various N splits, nitrogen applied in 3 splits (50% as basal + 25% at CRI + 25% at flowering) reflected lower density and dry weight of weeds, which was comparable with 2 N splits (50% as basal + 50% at CRI), but significantly superior to 3 equal splits (33.5% as basal + 33.5% at CRI + 33% at flowering). This might have happened owing to the influence of higher nitrogen at initial stage to improve crop growth as compared to the lower dose, which may have caused the smothering effect on weed growth and development. These findings are similar to those of Yadav *et al*. (2005).

Wheat

The highest leaf-area index (LAI), SPAD values, yield-attributing characters and yield were observed with ready-mixed application of Mesosulfuron-methyl + Iodosulfuron-methyl sodium (400 g/ha), followed by the tank mixed application of Clodinafop propargyl + Metsulfuron-methyl (60 + 4 g/ha) as compared to the weedy check (Table 2). Increasing nitrogen rates gradually increased the LAI and SPAD values, being significantly highest values at 150 kg N/ha. However, application of nitrogen as 50% basal + 25% at CRI + 25 flowering resulted in significantly higher LAI, SPAD values and yield-attributing characters (ear length, grains/ear, 1,000-grain weight) followed by 50% as basal + 50% at CRI being at par with 33.5% as basal + 33.5% at CRI + 33.0% at flowering (Table 2). The increase in LAI with higher nitrogen levels might be owing to more leaf area on account of more accumulation of assimilates. Ullah *et al*. (2013) reported an enhanced LAI by applying higher level of nitrogen. Application of Mesosulfuron-methyl + Iodosulfuron-methyl sodium (400 g/ha) and tank-mixed application of Clodinafop propargyl (60 g/ha) + Metsulfuron-methyl (4 g/ha) resulted in significantly 32.43% and 26.22% higher yield than weedy check, respectively. This might be due to reduced crop-weed competition throughout crop growth period (Table 2).

Enhanced nitrogen application from 120 to 150 kg N/ha resulted in a significant increase in LAI, SPAD value, N-uptake efficiency and grain yield. Application of 150 kg N/ha resulted significantly 13.60% higher grain yield over 120 kg N/ha as per the pooled data (Table 2). These results corroborate the findings of Bhat *et al*. (2006). However, split application of nitrogen also significantly increased

Table 1. Effect of weed-control treatments and nitrogen scheduling on weed density, biomass and weed-control efficiency (pooled data of 2 years)

Treatment	Weed density (No./m^2)		Weed biomass (g/m^2)		Weed control efficiency (%)
	60 DAS	At harvesting	60 DAS	At harvesting	Mean
Weed-control options					
Mesosulfuron-methyl + Iodosulfuron-methyl sodium (400 g/ha)	5.61 (31.48)	2.58 (6.16)	5.22 (26.73)	2.04 (3.68)	74.60
Clodinafop propargyl + Metsulfuron-methyl (60 + 4 g/ha)	5.99 (35.44)	2.92 (8.04)	5.64 (31.33)	2.35 (5.04)	65.22
Weedy check	8.42 (70.43)	4.07 (16.06)	7.97 (62.98)	3.87 (14.49)	–
SEm±	0.12	0.12	0.14	0.09	–
CD (P=0.05)	0.33	0.34	0.38	0.26	–
Nitrogen rate					
120 kg/ha	6.31 (39.33)	3.12 (9.24)	5.99 (35.43)	2.79 (7.31)	49.55
150 kg/ha	5.43 (28.97)	2.64 (6.45)	5.41 (28.79)	2.35 (5.02)	65.36
SEm±	0.15	0.14	0.16	0.13	–
CD (P=0.05)	0.43	0.38	0.44	0.37	–
Time of nitrogen application					
50% as basal + 50% at CRI	5.86 (33.81)	2.57 (6.11)	5.55 (30.25)	2.31 (4.83)	66.67
50% as basal + 25% at CRI + 25% at flowering	5.59 (30.77)	2.51 (5.81)	5.28 (27.34)	2.20 (4.36)	69.91
33.5% as basal + 33.5% at CRI + 33.0% at flowering	6.26 (38.74)	3.00 (8.52)	5.93 (34.63)	2.65 (6.51)	55.07
SEm±	0.11	0.12	0.10	0.09	
CD (P=0.05)	0.31	0.33	0.28	0.24	

DAS, Days after sowing; CRI, crown-root intitation grain yield of wheat. Three-split application of nitrogen, i.e. 50% as basal + 25% at CRI + 25% at flowering, recorded higher grain yield followed by 2 splits of nitrogen (50% as basal + 50% at CRI) and 3 equal splits of nitrogen (33.5% as basal + 33.5% at CRI + 33.0% at flowering). Three spilts of nitrogen application (50% as basal + 25% at CRI + 25% at flowering) recorded 9.04% higher grain yield over 50% as basal + 50% at CRI and 11.98% higher than 3 equal split of nitrogen. The result confirm the findings of Samara and Dhillon (2002).

Interaction effect

Significant interaction effect of weed-management options and nitrogen levels was observed on wheat productivity during both the years of study (Table 3). Application of premixed Mesosulfuron-methyl + Iodosulfuron-methyl sodium (400 g/ha) with higher level of nitrogen (150 kg/ha) produced highest grain yield (4.37 and 4.65 t/ha) as compared to tank-mixed Clodinafop propargyl + Metsulfuron methyl application. This effect on grain yield was observed in nitrogen dose and time of application also. Application of nitrogen at 150 kg/ha applied in 3 splits (50% as basal + 25% at CRI + 25% at flowering) recorded significantly higher wheat productivity than all the nitrogen scheduling combinations.

Nutrient uptake

The difference in total nutrient uptake (NPK) by the crop under different weed-management was noticed in the present study (Table 4). Weed-management practices significantly reduced NPK uptake by weeds and enhanced nutrient uptake by the crop. Among weed-management options, application of Mesosulfuron-methyl + Iodosulfuron-methyl sodium (400 g/ha) increased the availability of nutrients by minimizing crop-weed competition and resulted in more dry-matter accumulation in the crop, which was ultimately reflected in more nutrient uptake and nitrogen-uptake efficiency. Our findings are similar to the results reported by Chopra *et al*. (2008).

Total uptake of N, P and K in wheat grain and straw was increased significantly with the increased nitrogen level (150 kg/ha), while a significant decline in nitrogen-uptake efficiency was observed under the weedy check. The low uptake of these nutrients under lower level of ni-

Table 2. Effect of weed-control options and nitrogen scheduling on leaf-area index, SPAD value, yield-attributing characters, grain yield and economics in wheat (pooled data of 2 years)

Treatment	Ear length (cm)	Grains/ ear	1,000-grain weight(g)	Leaf-area index	SPAD Value	Grain yield (t/ha)	Economics			
							Cost of cultivation ($\times 10^3$ ₹/ha)	Gross returns ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	Benefit: cost ratio
Weed-control options										
Mesosulfuron-methyl + Iodosulfuron-methyl sodium (400 g/ha)	12.45	57.52	39.65	4.01	43.10	4.04	28.13	54.5	26.41	1.94
Clodinafop propargyl + Metsulfuron-methyl (60 + 4 g/ha)	11.95	56.92	38.84	3.83	41.20	3.70	26.82	49.9	23.13	1.86
Weedy check	9.62	47.85	32.70	3.41	38.90	2.73	25.93	36.8	10.92	1.42
SEm±	0.15	0.18	0.23	0.05	0.51	0.07	-	0.44	0.40	0.03
CD (P=0.05)	0.44	0.52	0.66	0.13	1.49	0.20	-	1.32	1.24	0.07
Nitrogen rate										
120 kg/ha	11.45	54.36	36.82	3.42	39.95	3.62	26.73	48.87	22.13	1.83
150 kg/ha	12.20	56.22	38.40	3.89	42.45	4.19	27.39	56.56	29.17	2.02
SEm±	0.24	0.49	0.50	0.06	0.45	0.10	-	0.53	0.43	0.04
CD (P=0.05)	0.66	1.35	1.42	0.17	1.22	0.28	-	1.57	1.27	0.12
Time of nitrogen application										
50% as basal + 50% at CRI	11.25	54.89	37.40	3.69	41.05	3.72	27.56	50.22	22.66	1.82
50% as basal + 25% at CRI + 25% at flowering	11.89	55.57	38.20	3.88	42.05	4.09	27.86	55.21	27.35	1.98
33.5% as basal + 33.0% at CRI + 33.0% at flowering	11.15	53.61	36.15	3.58	39.85	3.60	27.86	48.60	20.74	1.74
SEm±	0.19	0.18	0.25	0.05	0.55	0.06	-	0.49	0.45	0.05
CD (P=0.05)	0.54	0.49	0.72	0.14	1.54	0.17	-	1.49	1.36	0.14

trogen may be attributed to less plant biomass. Sinebo *et al*. (2004) also reported that N-uptake efficiency was higher at lower dose of nitrogen application (120 kg/ha), but drastically decreased with a further increase in the rate of the nutrient uptake. However, application of nitrogen in 3 splits (50% as basal + 25% at CRI + 25% at flowering) coinciding with crop requirements might have reduced rapid mineralization and losses through different pathways and thereby increased nutrient contents in wheat grain and straw that resulted in increased biomass of wheat plant owing to higher uptake of N, P and K.

Scheduling of nitrogen showed that higher N-uptake efficiency by the crop was recorded when nitrogen was applied in 3 splits–50% as basal + 25% at CRI + 25% at flowering-regardless of the dose of nitrogen at each time. Thus, compared to the 2 splits of N application, i.e. 50% as basal + 50% at CRI, the 3 split applications resulted significantly higher uptake efficiencies. Similar to these results, Tran and Tremblay (2000) also indicated lower N uptake efficiency in the early applications of N fertilizer at planting and tillering, compared to applications in the later stage of crop growth.

Economics

Among the weed-control treatments, the highest cost of cultivation was incurred under the application of Mesosulfuron-methyl + Iodosulfuron-methyl when compared with rest of the treatments (Table 2). All weed-control options exhibited higher gross and net returns than the weedy check as per the 2 year pooled data. Among the herbicides mixtures, Mesosulfuron-methyl + Iodosulfuron-methyl (400 g/ha) provided the highest net returns (₹26,410/ha) and benefit: cost (B:C) ratio (1.94:1). Between 2 nitrogen application rates, the highest net re-

Table 3. Interaction effect of weed-management options, nitrogen levels and its time of application on grain yield of wheat

Treatment	Grain yield (t/ha)											
	2014–15			2015–16			2014–15			2015–16		
	W_1	W_2	W_3	W_1	W_2	W_3	T_1	T_2	T_3	T_1	T_2	T_3
120 kg N/ha	3.95	3.82	2.79	4.13	3.99	3.01	3.42	4.12	3.02	3.49	4.22	3.42
160 kg N/ha	4.37	4.12	3.72	4.65	4.36	3.89	4.10	4.52	3.59	4.21	4.62	4.07
CD (P=0.05)		0.27			0.32			0.39			0.34	

W_1, Mesosulfuron-methyl + Iodosulfuron-methyl sodium (400 g/ha); W_2, Clodinafop propargyl + Metsulfuron-methyl (60 + 4 g/ha); W_3, weedy check; T_1, 50% as basal + 50% at corwn-root initiation (CRI); T_2, 50% as basal + 25% at CRI + 25% at flowering; T_3, 33.5% as basal + 33.5% at CRI + 33.0% at flowering

Table 4. Effect of weed-control options and nitrogen scehduling on nutrient uptake and nitrogen uptake efficiency in wheat crop (pooled data of 2 years)

Treatment	Nutrient uptake (kg/ha)			N uptake efficiency (%)
	N	P	K	
Weed-control options				
Mesosulfuron-methyl + Iodosulfuron-methyl sodium (400 g/ha)	111.1	22.7	106.8	82.3
Clodinafop propargyl + Metsulfuron-methyl (60 + 4 g/ha)	104.1	19.5	95.8	77.4
Weedy check	74.3	13.3	69.7	55.1
SEm±	3.0	0.6	5.1	1.6
CD (P=0.05)	8.5	1.7	14.1	4.6
Nitrogen rate				
120 kg/ha	90.2	16.9	84.1	75.2
150 kg/ha	104.8	19.8	92.2	69.9
SEm±	2.7	0.5	2.3	1.5
CD (P=0.05)	7.7	1.4	6.4	4.4
Time of nitrogen application				
50% as basal + 50% at CRI	95.8	20.0	88.8	71.0
50% as basal + 25% at CRI + 25% at flowering	109.8	22.1	104.4	81.4
33.5% as basal + 33.5% at CRI + 33.0% at flowering	86.2	17.4	65.0	63.9
SEm±	3.7	0.6	4.9	2.8
CD (P=0.05)	10.2	1.7	13.4	8.4

CRI, Crown-root initiation

turns (₹29,170) and B : C ratio (2.02:1) was found under the application of 150 kg N/ha followed by 120 kg N/ha. Difference in economic gains was also observed with the time of nitrogen application. The higher returns and B:C ratio were gained when N was applied in 3 splits–50% as basal + 25% at CRI stage and 25% at flowering stage than 2 splits of N application.

Hence, it may be concluded that post-emergence application of premixed Mesosulfuron + Iodosulfuron (400 g/ha) along with 150 kg N/ha applied 50% as basal + 25% at crown-root initiation + 25% at flowering could be a best option for achieving higher yield, net returns, benefit: cost ratio as well as significant weed suppression in wheat.

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