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Impact of nitrogen application on the performance of wheat (*Triticum aestivum*) and nitrogen use efficiency under different dates of sowing

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ABSTRACT

Field experiments were conducted during *rabi* seasons of 2003-04 and 2004-05 to find out the effect of sowing time and nitrogen schedules on perofrmance of wheat and N balance in sandy loam soils of Hisar, Haryana .The results showed that 40 days delayed sowing resulted in 24.5% reduction in wheat grain yield. However, there was increase in nitrogen content in grains with the delayed sowing whereas, nitrogen uptake decreased with delayed sowing. Maximum mobilization of nitrogen to grain was recorded on 25 December and minimum on 15 November sown crop. There was decrease in physiological efficiency (PE), agronomic efficiency (AE), nitrogen recovery (NR) and nitrogen use efficiency (NUE) by 8.4, 37, 9 and 8% respectively with delay in sowing from 15 November to 25 December. There was 4.14% increase in grain yield when N was applied as 45.3% of recommended N (150 kg) at sowing (F_4) followed by 50% at first irrigation and 4.7% as foliar application @ 3% concentration over recommended (F_1) schedule (50% at sowing and 50% at first irrigation) and 58.4% increase over no nitrogen application. About 60 kg/ha increase in nitrogen uptake was recorded in different nitrogen schedules over control. The highest nitrogen mobilization was observed in treatment where no nitrogen was applied and minimum in recommended schedule. NR, NUE and AE were 15.7%, 8.0% and 12% more under F_4 when compared with F_1 treatment. However, there was decrease of 6% in PE under F_4 than F_1 treatment. The highest B:C ratio was also recorded in early sowing and in F_4 treatment .

Key words: Nitrogen, Nitrogen metabolism, Nutrient uptake, Sowing date

India ranks second in the world with 74.9 millon tonnes (12% of the world) production of wheat from an area of 28.5 m ha (Anonymous, 2007). The nitrogen (N) application in wheat is aimed at providing nutrient in sufficient quantity to meet the crop demand, avoiding excess availability, leaching losses and ultimately increasing its efficiency. Therefore, the continuous availability of N to wheat during various phases of its growth and development is important factors which influence the grain quality and yield of wheat. The top dressing of N at later stage of the crop proved most effective in increasing grain protein concentration, yield and fertilizer use efficiency (Krishna Kumari *et al*., 2000). The N content in grain and stover and its apparent recovery increased with application at mid-tillering stage as compared to all application at sowing. Further, split application of N to wheat exhibited marked advantage for grain and total N uptake, and resulted in its yield enhancing effect (Geleto *et al*., 1996). Similarly, the sowing time is the most important factor determining the yield of wheat. The nutrient content in grain and straw increased with delay in sowing of wheat whereas, uptake of these nutrients decreased as the sowing of wheat gets delayed (Kumar *et al.,* 1998).The N use efficiency was also greater in optimum and early sown crop compared to late sown crop. The delay in sowing may not permit proper vegetative growth of the crop due to high temperature during its reproductive stage and leading to forced maturity and low productivity. In view of these the present study was conducted to study the effect of timing of N application on N content, uptake, yield, recovery and N use efficiency of wheat sown under various dates.

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MATERIALS AND METHODS

Field experiments were conducted during *rabi* 2003-04 and 2004-05 at the Agronomy Research Area, CCS Haryana Agricultural University, Hisar ($29^0$17'N $75^0$77'E and 215.2 above mean sea level) in Haryana. The soil of the experimental site was sandy loam in texture, with pH 8.1, organic carbon 0.09 %, EC 0.31 dS/m and available N (133 kg/ha), P (12.4 kg/ha) and K (238 kg/ha). The experiment was laid out in split plot design with 4 replications.

Three sowing dates *viz.*, D_1 (15 November), D_2 (5 December), D_3 (25 December) as main plot treatments and 7 nitrogen schedule *i.e.* F_0 (no nitrogen), F_1 (75 kg N at sowing + 75 kg N at first irrigation), F_2 (50 kg N at sowing + 50 kg N at first irrigation + 50 kg N at anthesis), F_3 (37.5 kg N at sowing + 75 kg N at first irrigation + 37.5 kg N at anthesis), F_4 [68 kg N at sowing + 75 kg N at first irrigation + 7 kg N (3% urea spray) at anthesis], F_5 [50 kg N at sowing + 50 kg N at first irrigation + 43 kg N at anthesis + 7 kg N (3% urea spray) at milk stage], F_6 [37.5 kg N at sowing + 68 kg N at first irrigation + 37.5 kg N at anthesis + 7 kg N (3% urea spray) at milk stage] in sub-plot with four replicates. The 'PBW 343' wheat was sown in rows 22.5 cm apart using 100 kg/ha seed in all sowing dates. Phosphorus @ 27.5 kg/ha and $ZnSO_4$ @ 25 kg/ha was applied at the sowing. Potash was not added due to its high status in the experimental site. N use efficiency (NUE) is worked as product of physiological efficiency and nitrogen recovery.

RESULTS AND DISCUSSION

Grain and biological yield

The grain and biological yield decreased significantly as the sowing was delayed from normal sowing of 15 November to 5 December and 25 December (Table 1). The crop sown on 15 November recorded 24.5% higher grain yield (4.69 tonne/ha) than sown on 25 December (3.77 tonne/ha). Similarly the highest B: C ratio (0.52) was also recorded in early sown crop and minimum (0.20) in very late sown crop. The comparable trend was also observed in yield attributes (Table 2). The higher temperature at later stage of the crop in late sown condition leads to forced maturity and reduction in yield attributes and ultimately the grain yield. The timely sown crop gets an advantage of favourable (normal) temperature during its grain development period. Different schedule of N application recorded significantly higher grain yield when compared with control (no nitrogen). The foliar application of N at the reproductive phase increased the grain yield to the tune of 3%. There was 4.14% increase in grain yield in F_4 over F_1 (recommended schedule). Similar trend was observed in yield attributes (Table 2). The increased yield attributes and grain yield in foliar application during reproductive phase may be due to better distribution and consistent availability of nitrogen to the plant throughout the crop season, which helped the plants to grow better and sufficient supply of the nutrients to the grains during its development (Yue *et al*., 1998). The highest B: C ratio (0.46) was also recorded in F_4 (Table 2).

The interaction between sowing time and nitrogen application schedule on wheat grain yield was significant (Table 5). The delayed sowing from 15 November to 25 December reduced the grain yield significantly under all the nitrogen application schedules. But, the difference in grain yield of 15 November and 5 December were non significant.

Nitrogen content and uptake

Nitrogen content in grain increased significantly with delayed sowing and it was at par in straw (Table 1). The significantly lower nitrogen content in grain of timely sown crop may be due to dilution effect as the grain yield

Table 1. Effect of sowing time and nitrogen schedule on yield (t/ha), nitrogen content (%) and uptake (kg/ha) of wheat

Treatment	N content				Grain yield		Biological yield		N uptake					
	Grain		Straw		2003-04	2004-05			Grain		Straw		Total	
	2003-04	2004-05	2003-04	2004-05			2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05
Date of sowing														
15 November	1.77	1.81	0.54	0.59	5.00	4.37	4.69	11.47	89.0	79.7	44.0	42.0	133	122
5 December	1.81	1.85	0.52	0.56	4.69	4.06	4.37	10.64	85.5	75.2	39.7	37.5	125	113
25 December	1.86	1.89	0.50	0.55	4.14	3.40	3.77	9.10	77.2	64.6	34.5	32.0	112	97
SEm±	0.02	0.01	0.01	0.01	0.10	0.11	0.05	0.15	0.6	0.8	0.6	0.5	1	1
CD(P=0.05)	0.04	0.03	NS	NS	0.30	0.26	0.14	0.42	1.5	1.7	1.6	1.1	3	2
Nitrogen schedule														
F_0	1.62	1.64	0.42	0.43	3.14	2.68	8.44	7.27	50.8	44.0	22.4	20.2	73.2	64
F_1	1.78	1.80	0.55	0.59	4.75	4.08	12.39	10.82	84.4	73.6	42.3	40.2	127	114
F_2	1.80	1.85	0.55	0.60	4.72	4.07	12.44	10.81	85.3	75.0	42.7	39.3	128	114
F_3	1.83	1.87	0.56	0.59	4.78	4.17	12.52	10.86	87.3	77.8	43.3	39.3	131	117
F_4	1.88	1.94	0.54	0.58	4.99	4.21	12.83	11.03	93.8	81.5	42.0	39.1	136	121
F_5	1.88	1.92	0.54	0.58	4.92	4.17	12.77	10.99	92.3	80.0	42.2	39.5	135	120
F_6	1.89	1.93	0.52	0.59	4.97	4.21	12.84	11.07	93.7	80.9	40.7	40.2	134	121
SEm±	0.03	0.04	0.02	0.02	0.10	0.05	0.16	0.08	1.0	0.5	0.9	0.8	3	2
CD(P=0.05)	0.10	0.13	0.06	0.05	0.25	0.12	0.35	0.18	2.2	1.4	2.4	2.7	8	5

was significantly higher in timely sown crop than in 25 December sown crop. The nitrogen uptake in grain and straw decreased with delay in sowing. There was significant increase in nitrogen content in grain and as well as in straw under nitrogen schedule treatments as compared to control. There was 13.5 kg/ha reduction in nitrogen uptake by grain and 10 kg/ha by straw, when the crop was sown on 25 December than the timely sown (15 November). These variations in uptake of nitrogen by wheat crop under different sowing dates were due to variations in nitrogen content and yield of grain and straw. The higher nitrogen uptake (23 kg/ha) recorded both by grain and straw of wheat in timely sown crop may be due to 2.29 t/ha more biomass production and 31 days longer crop duration. These results are in conformity with the findings of Sharma and Gupta (2003).

The total nitrogen uptake by wheat crop was 15 kg more during 2003-04 than 2004-05 in all the treatments (Table 1). The higher uptake during first year of study may be due to better environmental conditions prevailed during first year in available radiation, whereas in second year higher humidity due to excessive rains resulted in develop-

Table 2. Effect of sowing time and nitrogen schedules on yield attributes and economics of wheat

Treatment	No. of effective tillers/mrl		No. of spikelets/spike		No. of grains/spike		Test weight		Cost of cultivation (x 10^3 Rs/ha)	Net monetary return (x 10^3 Rs/ha)	B.C ratio
	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05			
Date of sowing											
15 November	89.4	84.9	21.0	18.0	46.0	39.7	43.9	43.1	26.14	13.58	0.52
5 December	86.5	81.1	19.1	18.0	44.0	36.1	42.4	39.1	25.64	10.98	0.43
25 December	81.9	77.4	18.4	17.8	40.2	34.0	38.3	37.8	25.64	5.03	0.20
SEm±	0.4	0.6	0.5	0.4	0.6	0.5	0.3	0.3			
CD(P=0.05)	1.4	1.7	1.5	NS	1.5	1.7	1.1	0.9			
Nitrogen schedule											
F_0	74.6	70.5	18.0	16.2	35.7	29.9	40.2	38.6	22.96	1.72	0.07
F_1	87.0	81.9	19.2	17.8	42.7	36.9	40.9	39.4	25.77	11.36	0.44
F_2	87.4	84.2	19.3	17.8	43.3	36.8	41.2	39.8	26.00	10.84	0.42
F_3	87.7	83.3	19.3	17.8	43.2	36.5	41.6	40.8	26.06	11.41	0.42
F_4	89.7	84.5	20.5	19.0	45.8	39.4	42.2	40.3	26.17	12.10	0.46
F_5	89.0	84.8	20.2	18.2	43.0	37.8	41.8	40.2	26.27	11.72	0.45
F_6	90.0	84.7	19.8	18.8	44.3	39.2	42.7	40.7	26.27	12.00	0.45
SEm±	1.1	1.4	0.5	0.4	0.7	0.9	0.4	0.5			
CD(P=0.05)	3.1	3.5	1.3	1.4	1.9	2.4	NS	1.3			

Table 3. Effect of sowing time and nitrogen schedules on nitrogen mobilization from straw to grain in wheat

Treatment	Nitrogen at anthesis (kg/ha)		Nitrogen at physiological maturity (kg/ha)		Nitrogen mobilization (%)	
	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05
Date of sowing						
15 November	88.0	88.8	44.9	41.3	48.9	53.5
5 December	83.5	83.0	37.1	37.9	55.4	54.6
25 December	87.2	90.9	34.5	36.8	60.5	59.8
SEm±	1.1	1.3	1.0	0.4	1.0	0.9
CD(P=0.05)	3.0	3.7	2.7	0.8	2.9	2.6
Nitrogen schedule						
F_0	63.6	62.2	26.1	23.7	58.9	61.8
F_1	89.6	91.4	43.0	43.0	51.5	52.4
F_2	91.3	92.7	41.4	40.6	54.5	56.1
F_3	88.5	91.8	41.5	41.5	53.0	54.5
F_4	91.8	92.5	41.0	40.6	55.2	55.9
F_5	88.1	89.3	39.2	39.3	55.3	55.7
F_6	90.8	93.1	39.7	41.6	56.2	55.1
SEm±	2.0	2.1	1.0	0.6	1.5	1.2
CD(P=0.05)	5.8	5.5	2.3	1.7	4.3	3.4

ment of brown rust disease, which caused yield reduction. The higher growth and yield during first year may be due to more absorption of nutrients from the soil and spray, hence, resulted in higher uptake. The significant increase (about 60 kg/ha) in the nitrogen uptake in different application schedules over control may be due to higher readily availability of nitrogen in various nitrogen application schedules than in control. The results corroborate with the findings of Saren and Jana (2001) and Bellido *et al.* (2005). This fact is also confirmed by recording significantly higher N content in grain (0.28%) and straw (0.16%) in nitrogen application schedule treatments than control (Table1). Higher uptake in split applications and 3% urea spray at reproductive phase over soil applied schedules may be because of higher absorption due to direct availability of urea to the crop canopy particularly at reproductive phase. At this stage, crop requirement for nutrients is high for the development of protein rich sink in the form of grain and nutrient absorption capacity of roots declined due to aging factor. The ratio of total N uptake through grain and straw was 2:1 in N applied treatments whereas, it was wider in control treatment due to less availability of nutrient from the soil and higher translocation from source to sink whereas, in split application of nitrogen the plants get readily available nitrogen throughout the crop season.

The total N uptake and protein content in wheat had significant interaction between sowing time and nitrogen application schedules (Table 5).The N uptake by wheat decreased and protein content increased significantly with delayed sowing under all nitrogen application schedules except control (F_0). Significantly higher N uptake and protein content was recorded in foliar applied N (F_4, F_5, F_6) than soil applied (F_1, F_2, F_3) in timely sown wheat and under late sown wheat.

Mobilization of nitrogen to grain

The maximum nitrogen mobilization was recorded in 25 December sown wheat and minimum in 15 November sown crop (Table 3). Under late sown conditions, the supra-optimal temperature prevailing during the critical grain filling stage caused the forced maturity. Under high temperature conditions, the crop inspite of absorbing more nutrients from the soil started translocating the nitrogen from the crop canopy due to senescence of leaves and roots. This fact can further be strengthened by the 5% and 7% higher mobilization of nitrogen from vegetative plant parts to developing grain after anthesis in very late sown (25 December) over timely sown crop (15 November). These results also corroborate the findings of Tyagi *et al.* (2003). Among the nitrogen schedule treatments, F_1 to F_6 significantly reduced the biomass mobilization as compared to F_0 (control). The highest nitrogen mobilization was observed in F_0 and minimum in F_1 treatment. The nitrogen mobilization in F_1, F_2 and F_3 decreased significantly over F_0 (control), but showed non-significant differences with F_4, F_5 and F_6 during 2003-04 whereas during the year 2004-05, all the nitrogen scheduling treatments significantly reduced the nitrogen mobilization from straw to grain over control and were at par with each other.

Nitrogen recovery and efficiencies

The decrease to the tune of 8.4%, 37%, 9%, 8% in physiological efficiency (PE), agronomic efficiency (AE),

Table 4. Effect of sowing time and nitrogen schedule on nitrogen recovery and efficiencies in wheat

Treatment	Physiological efficiency (kg/kg)			Agronomic efficiency (kg/kg)			Nitrogen recovery (%)			Nitrogen use efficiency (%)		
	2003-04	2004-05	Mean	2003-04	2004-05	Mean	2003-04	2004-05	Mean	2003-04	2004-05	Mean
Date of sowing												
15November	72.2	68.6	70.4	12.6	11.1	11.9	42.2	39.3	40.8	30.4	26.9	28.6
5 December	74.8	70.6	72.7	12.6	11.2	11.8	41.7	39.7	40.7	31.6	27.8	29.7
25 December	66.6	62.3	64.5	9.2	7.2	8.2	33.1	29.5	31.3	21.9	18.4	20.1
SEm±	1.0	0.9		0.2	0.1		0.3	0.1		0.5	0.8	
CD(P=0.05)	2.6	2.4		0.5	0.3		1.0	2.0		1.6	2.0	
Nitrogen schedule												
F_0												
F_1	73.7	71.0	72.4	10.8	9.3	10.0	35.7	33.1	34.4	26.4	23.7	25.0
F_2	72.5	70.5	71.5	10.6	9.3	9.9	36.5	33.4	34.9	26.7	23.6	25.1
F_3	70.9	67.6	69.3	11.0	9.9	10.4	38.2	35.3	36.7	27.2	24.0	25.6
F_4	70.0	66.5	68.3	12.3	10.2	11.2	41.9	37.8	39.8	29.3	24.8	27.0
F_5	70.5	67.0	68.8	11.9	10.1	11.0	40.9	37.0	38.9	28.8	24.8	26.8
F_6	71.5	66.4	69.0	12.2	10.2	11.2	40.8	37.9	39.3	29.4	25.3	27.3
SEm±	0.2	0.3		0.3	0.2		0.6	0.5		0.5	0.4	
CD(P=0.05)	NS	NS		0.7	0.5		1.6	1.5		1.6	1.1	

Table 5. Interaction effect of sowing time and nitrogen schedules on grain yield, total N uptake, nitrogen use efficiency, nitrogen recovery and protein content of wheat.

Nitrogen schedule	Date of sowing		
	D_1	D_2	D_3
		Grain yield (tonne/ha)	
F_0	3.17	2.84	2.71
F_1	4.85	4.48	3.91
F_2	4.84	4.49	3.87
F_3	4.89	4.65	3.88
F_4	5.01	4.74	4.04
F_5	4.93	4.70	3.96
F_6	5.05	4.72	3.99
SEm±		0.14	
CD(P=0.05)		0.40	
		Total N uptake (kg/ha)	
F_0	74.9	66.8	64.2
F_1	131.6	122.2	107.0
F_2	133.3	123.6	106.6
F_3	133.9	128.6	109.0
F_4	140.0	130.9	113.7
F_5	137.9	130.9	112.1
F_6	139.3	131.1	112.9
SEm±		5.0	
CD(P=0.05)		14.1	
		Nitrogen use efficiency (%)	
F_0			
F_1	27.65	27.90	19.45
F_2	27.60	28.70	19.15
F_3	27.85	29.55	19.35
F_4	29.35	30.50	21.35
F_5	29.25	30.55	20.65
F_6	30.10	30.85	21.00
SEm±		1.10	
CD(P=0.05)		3.00	
		Nitrogen recovery (%)	
F_0			
F_1	37.8	36.9	28.5
F_2	38.8	37.8	28.2
F_3	39.3	41.1	29.9
F_4	43.4	42.7	32.9
F_5	42.0	42.7	31.9
F_6	42.4	42.8	32.5
SEm±		0.9	
CD(P=0.05)		2.5	
		Protein content (%)	
F_0	10.4	10.6	10.8
F_1	10.6	11.0	11.4
F_2	10.8	11.2	11.7
F_3	10.7	11.2	11.9
F_4	12.2	12.6	13.1
F_5	12.1	12.4	13.0
F_6	12.1	12.4	13.0
SEm±		0.3	
CD(P=0.05)		0.7	

nitrogen recovery (NR) and nitrogen use efficiency(NUE), respectively recorded in 25 December showing when compared with 15 November sown crop (Table 4). However, the difference in sowing dates of 15 November and 5 December was at par. The reduction in recovery and efficiencies due to delayed sowing may be due to reduction in crop growth and grain yield as a result of unfavourable environment both at early vegetative and late reproductive phase of the crop. This sub-optimal and supra-optimal atmospheric temperature delayed the crop emergence along with reduction in duration of the crop.

The higher recovery and efficiency of N applied to wheat crop under different treatments during 2003-04 than 2004-05 was owing to higher yield (Table1). These results further strengthened by highly significant association of grain yield with nitrogen content in straw (r=0.94), nitrogen content in grain (r=0.74), nitrogen uptake by grain (r=0.98), total nitrogen uptake (r=0.99), PE (r=0.91), AE (0.96), NR (r=0.96), NUE (r=0.96). The increased split applications of nitrogen and foliar spray also increased the PE and AE. The NR, NUE and AE recorded were 15.7, 8.0 and 12% more in F_4 when compared with F_1 (recommended schedule), respectively. Whereas, 6% decrease in PE was recorded in F_4 than F_1 treatment. Wuest and Cassman (1992) also observed NUE and recovery of nitrogen to the tune of 30 to 55% when N was applied at sowing of the crop. However, it can be enhanced to 55 to 88% when it was applied at the anthesis. The higher NUE can also be explained through higher nitrogen uptake of grain and total nitrogen uptake by wheat crop through grain and straw.

The interaction of sowing time and nitrogen application schedule on NUE and NR were found significant (Table 5). The delay in sowing from 5 December to 25 December reduced the NUE significantly under all the nitrogen application schedules. But, the difference in F_1 to F_6 were non-significant under all the dates of sowing. The nitrogen applied in four splits (foliar spray) increased NR under all dates of sowing over N applied in 2 or 3 splits applied through soil.

In view of these findings, it may be concluded that there was significant reduction in the grain yield of the wheat when its sowing gets delayed from 15 November to 5 December and 25 December. To get the highest NUE, protein content in the grain and B: C ratio, N may be applied in 3 splits (68 kg N at sowing + 75 kg N at first irrigation + 7 kg N (3% urea spray) at anthesis).

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