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Influence of the Source and Rate of Nitrogenous Fertilizer and Irrigation Depth on Fertilizer N-Recovery and Grain Yield of Wheat

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ABSTRACT

A field experiment was conducted on wheat (cv. TJ-83) to investigate the effect of nitrogen (N) source (urea and ammonium nitrate), N rate (0, 100, 150 and 200 kg N ha^{-1}) and irrigation depth (5, 7.5 and 10 cm) on N-recovery and grain yield of wheat. The treatments were arranged in a split-plot design, with irrigation as a major split. All the treatments received basal application of 90 kg P_2O_5 and 60 kg K_2O per hectare. The soil was a Miani series with 45% clay in surface soil, alkaline (pH 7.9) and calcareous (lime 7.7%) in nature. Organic matter and mineral N contents of the surface soil were 0.65% and 26 mg kg^{-1}, respectively. The data showed that wheat growth and yield were maximum at 100 kg N ha^{-1} for each source of N. Further increase in N rate did not significantly influence the yield. The growth parameters showed non-significant influence in case of depth of irrigation, except the number of productive tillers per plant. The interaction between N and irrigation depth was also non-significant. Nitrogen uptake increased continuously up to the highest N rate, while the grain and straw yields were maximum at 100 kg N ha^{-1}. The N uptake was not influenced by N source and irrigation treatments. The maximum N recovery (35.7%) was noted when urea was applied at the rate of 100 kg N ha^{-1}, under the irrigation depth of 5 cm. The corresponding value for ammonium nitrate was 30%. A decrease in N-recovery was noted as N-rate increased beyond 100 kg N ha^{-1} or when irrigation depth was more than 5 cm per irrigation.

Key Words: Nitrogen source; Nitrogen rate; Irrigation depth; Fertilizer nitrogen recovery; Wheat grain yield

INTRODUCTION

Nitrogen (N) is the most deficient major nutrient in Pakistan soils and elsewhere. Crop nutrition is, therefore, generally supplemented through application of nitrogenous fertilizers. Use efficiency of N fertilizers is only about 50% in most cases, which is attributed to N losses through volatilization, denitrification, and leaching. Volatilization losses occur due to surface application of ammonical fertilizer to the soil having both high pH and temperature. The loss of nitrogen through leaching is exclusively due to the movement of soluble NO_3 with water. The over all objective of any nitrogen management programme should be to increase the efficiency of N-utilization by crops. Factors like rate and source of N, method of N application, timing and frequency of fertilizer application in relation to stage of growth, depth and frequency of irrigation, etc. are of great significance for increasing the N utilization by crops, and thus reducing the losses of N through leaching (Rashid & Salim, 1991; Ahmed, 1994; Zia *et al.*, 1997; Siddique *et al.*, 2004). These factors can be grouped into two broad headings; one dealing with N-fertilizer and the other dealing with irrigation aspects.

Soil water contents control the availability of essential nutrients to plants and also affect nutrient uptake and root growth (Olsen *et al.*, 1961; Mirrch & Ketcheson, 1973). Irrigation water must therefore be applied according to crop water requirements (Pakistan Council of Research in Water Resources, 2002) in order to maintain proper soil moisture condition and provide for efficient use of water and nutrients. Currently practiced flood irrigation system can have adverse effects on the utilization efficiency of both water and the nutrients. It has been estimated that out of 84.58 MAF total water available at canal head (Government of Pakistan, 2000), nearly 50% of irrigation water is lost in transit to tertiary level irrigation system and at the farm during application to crops due to faulty agronomic practices (Malik & Nasim, 2005).

Indeed irrigation water management and N leaching are closely linked. Efficient water management can simultaneously help reduce N losses through leaching. The source, rate and timing of N fertilizer application will have an important bearing upon the above relationship between water management and N-leaching. This study was, therefore, designed to evaluate the effect of source and rate of N fertilizer and irrigation depth on growth, fertilizer N recovery and grain yield of wheat.

MATERIALS AND METHODS

A field experiment was conducted on wheat (cv. TJ-83) involving the factorial combination of two N sources (urea and ammonium nitrate) with four rates (0, 100, 150 and 200 kg N ha^{-1}) and three depths of irrigation (5, 7.5 & 10 cm). The treatments were replicated four times in a split plot design, with depth of irrigation as major split. Fertilizer treatments were assigned to sub-plots on random basis. The soaking irrigation was applied on 23rd November and sowing was done on 4th December at seed rate of 125 kg ha^{-1}. A basal dose of phosphorus (90 kg P_2O_5 ha^{-1}) and potassium (50 kg K_2O ha^{-1}) was applied before sowing. Nitrogen was applied in two equal splits, one at the time of sowing and other at first irrigation. The irrigation treatments were imposed by using calibrated siphon with stream size of 1.89 L sec^{-1}. The time required for irrigation was calculated by using following formula:

$$T = \frac{Qt \times A \times d}{Q \times \text{No. of siphons used}}$$

Where T = Time required in hours for irrigating "A" hectares of land, Q = Size of stream (1.89 L sec^{-1}.), t = 14.5696 (Calculated factor), A = Area in hectares, d = Depth of irrigation.

Total quantity of irrigation water applied to wheat crop from sowing to maturity was kept constant at 40 cm for each treatment. The first irrigation was kept at 10 cm in each case, because 5 or 7.5 cm was not enough to soak the entire soil area of each plot, uniformly. However, the treatment plan for depth of irrigation was strictly followed for subsequent irrigations. The crop was irrigated 6, 4 and 3 times during the cropping season times by applying 5, 7.5, and 10 cm irrigation, respectively, after soaking dose. Before planting and fertilizer application, composite soil samples, comprising five sub-samples, were drawn from each of the four depths (0-15, 15-30, 30-60 & 60-90 cm) and analyzed for various physico-chemical properties (Table I). Plant samples of index tissue (flag leaf, 30 leaves per treatment) were collected at 50% head emergence, while the straw and grain samples were collected at harvesting (five plants from each treatment). The plant samples were analyzed for total N by wet digestion (H_2SO_4/Se/H_2O_2), followed by distillation using Kjeldahl method (Winkleman *et al.*, 1990). The plant N data were utilized to calculate total N uptake and fertilizer N recovery for each treatment.

Table I. Physico-chemical properties of the soil used in the study

Determination	Depth (cm)			
	0-15	15-30	30-60	60-90
Particle size distribution				
Sand (%)	21.9	21.2	25.8	22.8
Silt (%)	32.7	36.4	44.1	46.6
Clay (%)	45.4	42.4	30.1	30.6
Textural class	Clay	Clay	Clay loam	Clay loam
Soil series			Miani	
pH	7.9	7.9	7.9	7.9
Electrical conductivity (dS m^{-1})	0.31	0.23	0.24	0.21
$CaCO_3$ (%)	7.7	7.1	6.8	6.3
Organic matter (%)	0.65	0.52	0.34	0.26
Olsen P (mg kg^{-1})	4.9	3.6	2.3	1.3
Mineral N (mg kg^{-1})				
i. Ammonical	15.0	8.0	7.0	4.0
ii. Nitrate	11.0	7.0	8.0	3.0
Total nitrogen (mg kg^{-1})	335	265	178	119
Exchangeable cations (me g^{-100})				
Ca	25.20	29.95	23.95	29.55
Mg	17.16	15.51	18.33	15.24
K	0.59	0.56	0.46	0.31
Na	1.45	1.65	2.12	1.57

RESULTS AND DISCUSSION

Growth parameters. The data (Table II) revealed that N application significantly increased all the growth parameters except 1000-grain weight, which showed decline at the highest N rates. Expressed on percentage basis, the number of productive tillers per plant, plant height and ear head length increased by 55.8, 18.9 and 11.7%, respectively over control (no nitrogen). The results of these parameters are in agreement with those of Gupta and Singh (1971), Nadeem *et al.* (1994), Zia *et al.* (1994) and Ashraf (1994). The oven dry weight of flag leaves (30 leaves per treatment), collected at 50% head emergence, showed significant increase (25.9%) at 100 kg N ha^{-1}, over control (Table II). Application of N in excess of 100 kg N ha^{-1} resulted in slight decline (non-significant) in dry weight of flag leaves. It was further noted that none of the growth parameters were affected by the source of N fertilizer. Both the ammonical and nitrate-N sources behaved in a same way. Moreover, there was no effect of irrigation depths on any growth parameter with the exception of the number of productive tillers per plant, which decreased significantly as irrigation depth was increased from 5 to 10 cm per irrigation. The interaction between depth of irrigation and the N treatments had non-significant effect on growth parameters.

Yield. A highly significant increase in the straw and grain yield of wheat was obtained with the application of N fertilizers (Table III). Unfertilized control plots produced, on an average, 1777 kg grain per hectare, which was 65% of maximum yield (avg. 2732 kg N ha^{-1}) that was achieved at 100 kg N ha^{-1}. Further increase in N rates did not influence the grain or straw yield of wheat. Similar trend was recorded by Yasin (1991), Yasin *et al.* (1991), Rashid and Salim (1991), Saeed and Yousaf (1994), Farooq *et al.* (1994) and Nadeem *et al.* (1994). The effect of NH_4-N source (urea) and NO_3-N source (ammonium nitrate) was not significant. Similarly, the effect of irrigation depth was also non-significant whereby the average grain yields were 2462, 2375 and 2589 kg ha^{-1} corresponding to irrigation depth of 5, 7.5 and 10 cm, respectively. The data revealed that there was no influence of either N-source, irrigation depths, or the interaction of N and irrigation depth on the yield of wheat. Yasin *et al.* (1991) also reported that the depth of irrigation had no effect on the grain or straw yield of wheat.

Total N, and N uptake and recovery. A highly significant increase in total N content of flag leaf and that of straw and grain was observed with the application of N fertilizer (Table IV). On percentage basis, total N in flag leaf increased by 10.2, 16.5 and 19.9% over control with N application of 100, 150 and 200 kg ha^{-1}, respectively. The corresponding values for straw and grain were 42.3, 64.7 and 90.5% and 20.4, 31.7 and 41.6%, respectively.

Table II. Growth parameters of wheat as affected by source and rate of N fertilizers and irrigation depths

Irrigation depth (cm)	N rate (kg ha^{-1})	Productive tillers per plant			Plant height			Ear head length			Oven dry weight of flag leaves			1000 grain weight		
		Urea	AN	Avg.	Urea	AN	Avg.	Urea	AN	Avg.	Urea	AN	Avg.	Urea	AN	Avg.
5	0	3.2	3.2	3.2	62.4	62.4	62.4	12.2	12.2	12.2	2.04	2.04	2.04	30.86	30.86	30.86
	100	3.9	3.7	3.8	71.5	69.7	70.6	12.2	12.6	12.4	2.25	2.66	2.45	30.77	31.16	30.96
	150	4.1	3.9	4.0	72.7	71.2	71.9	13.1	12.7	12.9	2.28	2.35	2.31	27.34	30.90	29.12
	200	4.8	4.9	4.8	75.8	75.6	75.7	13.1	12.9	13.0	2.35	2.48	2.41	29.46	28.64	29.05
	Average	4.0	3.9	3.9	70.6	69.7	70.2	12.6	12.6	12.6	2.23	2.38	2.30	29.61	30.39	30.00
7.5	0	2.8	2.8	2.8	60.6	60.6	60.6	10.9	10.9	10.9	1.89	1.89	1.89	30.70	30.70	30.70
	100	3.7	3.6	3.7	66.9	66.3	66.6	11.7	11.8	11.7	2.42	2.61	2.51	30.64	31.25	31.94
	150	4.3	4.5	4.4	70.0	70.4	70.2	12.2	11.7	12.4	2.45	2.47	2.46	28.41	30.31	29.36
	200	4.5	4.5	4.5	71.4	72.7	72.1	12.5	12.5	12.5	2.52	2.32	2.42	28.29	29.10	28.69
	Average	3.8	3.9	3.8	67.2	67.5	67.4	11.8	12.0	11.9	2.32	2.32	2.32	29.51	30.34	29.92
10	0	2.6	2.6	2.6	62.5	62.5	62.5	11.2	11.2	11.2	1.86	1.86	1.86	33.35	33.35	33.35
	100	3.3	3.6	3.5	69.7	64.6	67.2	12.4	12.3	12.3	2.20	2.46	2.33	31.84	31.34	31.59
	150	3.9	4.1	4.0	69.8	71.2	72.7	12.8	11.8	12.3	2.04	2.23	2.13	30.08	30.99	30.53
	200	3.8	4.5	4.1	73.8	71.6	72.7	12.4	13.2	12.8	2.35	2.43	2.39	28.85	29.40	29.12
Average		3.4	3.7	3.5	68.9	67.5	68.2	12.2	12.1	12.2	2.11	2.24	2.18	31.03	31.27	31.15
Source Average		3.7	3.8	3.7	68.9	67.5	68.2	12.2	12.2	12.2	2.22	2.31	2.27	30.05	30.67	30.36
N control v/s others		** 0.39			** 1.83			** 0.62			** 0.35			** 1.49		
N rate		** 0.32			** 1.49			* 0.38			N.S.			** 1.58		
N sources		N.S.			N.S.			N.S.			N.S.			N.S.		
Irrigation		* 0.29			N.S.			N.S.			N.S.			N.S.		

** Significant at 0.01 level * Significant at 0.05 level N.S. Non-significant

Table III. Straw and grain yields of wheat as affected by source and rate of N fertilizer and irrigation depths

Irrigation depth (cm)	N rate (kg ha^{-1})	Straw yield (kg ha^{-1})			Grain yield (kg ha^{-1})		
		Urea	AN	Avg.	Urea	AN	Avg.
5	0	2007	2007	2007	1744	1744	1744
	100	4159	3486	3828	2772	2691	2732
	150	3731	3995	3863	2630	2569	2600
	200	4403	4525	4464	2630	2854	2742
	Average	3575	3503	3539	2452	2472	2462
7.5	0	1886	1886	1886	1713	1713	1713
	100	3425	3547	3486	2630	2691	2661
	150	3547	4281	3914	2508	2609	2559
	200	3853	3792	3823	2446	2691	2569
	Average	3178	3377	3277	2324	2426	2375
10	0	1794	1794	1794	1875	1875	1875
	100	3425	3669	3547	2752	2854	2803
	150	3751	3428	3590	2691	2772	2732
	200	4159	3731	3945	2772	3119	2946
Average		3282	3156	3219	2523	2655	2589
Source Average		3345	3345	3345	2433	2577	2475
N control v/s others		** 561			** 383		
N Rate		N.S.			N.S.		
N Source		N.S.			N.S.		
Irrigation		N.S.			N.S.		

** Significant at 0.01 Level N.S. Non-Significant

However, the effect of N rate beyond 100 kg ha^{-1} was non-significant in each case. Besides, there was no effect of N source, irrigation depth as well as the interaction between N and irrigation depth treatments.

Nitrogen uptake data (Table V) showed a highly significant increase with application of N fertilizer. On an average, it increased from 32.85 kg ha^{-1} (at control) to 78.96 kg ha^{-1} (at 200 kg N ha^{-1}). This was not consistent with the yield response of wheat. The straw and grain yields attended their maximum at 100 kg N ha^{-1}; whereas, N-uptake continued to increase up to 200 kg N ha^{-1}. Yasin *et al.* (1991), Farooq *et al.* (1994) and Zia *et al.* (1991) also reported increase in N uptake with the increasing N rates. Source of N, depth of irrigation and their interaction had no effect on N uptake in wheat.

Unlike N uptake, there was a decline in N recovery with an increase in rate of applied N. Similar results were reported by Farooq *et al.* (1994). The maximum N recovery of 30.7% (avg.) was noted at 100 kg N ha^{-1}, which decreased to 23.1% with application of 200 kg N ha^{-1}. The data clearly showed that the lower rates of N were efficiently utilized. Slight influence of irrigation depth on N-recovery was, however, noted whereby average N recovery was highest (27.97%) for irrigation depth of 5 cm per irrigation. The N recovery from the two sources was almost equal at irrigation depths of 5 and 7.5 cm. However, ammonium nitrate resulted in better recovery (30.2%) compared to urea (20.99%), at the irrigation depth of 10 cm per irrigation. The results are closely related to those reported by Christensen and Meirts (1982), Russell *et al.* (1979), Yasin *et al.* (1991), Farooq *et al.* (1994) and Zia *et al.* (1994).

CONCLUSION

It is concluded that 100 kg N ha^{-1}, applied as urea with light frequent irrigation (5 cm per irrigation), was most beneficial N-rate, source and depth of irrigation, respectively, for wheat in this package of conditions.

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Table IV. Total N content of flag leaves, straw and grain as affected by source and rate of N fertilizers irrigation depth

Irrigation depth (cm)	N rate (kg ha^{-1})	N content of flag leaves (%)			N content of straw (%)			N content of grain (%)		
		Urea	AN	Avg.	Urea	AN	Avg.	Urea	AN	Avg.
5	0	2.87	2.87	2.87	0.217	0.217	0.217	1.442	1.442	1.442
	100	3.35	3.16	3.25	0.287	0.304	0.296	1.974	1.883	1.929
	150	3.43	3.48	3.46	0.319	0.378	0.349	2.135	2.219	2.177
	200	3.49	3.49	3.49	0.403	0.402	0.403	2.318	2.282	2.300
	Average	3.26	3.25	3.27	0.307	0.325	0.316	1.967	1.957	1.962
7.5	0	3.39	3.39	3.39	0.214	0.214	0.214	1.848	1.848	1.848
	100	3.44	3.51	3.48	0.305	0.286	0.296	2.100	2.037	2.069
	150	3.52	3.58	3.55	0.383	0.322	0.353	2.191	2.198	2.195
	200	3.64	3.73	3.68	0.394	0.403	0.399	2.247	2.296	2.272
	Average	3.50	3.55	3.52	0.324	0.306	0.316	2.097	2.095	2.096
10	0	2.81	2.81	2.81	0.200	0.200	0.200	1.533	1.533	1.533
	100	3.35	3.18	3.27	0.287	0.325	0.306	1.666	1.953	1.810
	150	3.45	3.67	3.56	0.347	0.326	0.337	1.750	2.212	1.981
	200	3.61	3.78	3.70	0.397	0.402	0.400	2.072	2.445	2.259
	Average	3.30	3.36	3.33	0.308	0.313	0.311	1.755	2.036	1.896
	Source Average	3.35	3.39	3.36	0.313	0.315	0.314	1.940	2.029	1.985

N control v/s others	** 0.33	** 0.042	** 0.139
N rate	N.S.	** 0.190	** 0.186
N source	N.S.	N.S.	N.S.
Irrigation	N.S.	N.S.	N.S.
** Significant at 0.01 Level	* Significant at 0.05 Level.		N.S. Non-Significant

Table V. Total N uptake in wheat and fertilizer N recovery as affected by source and rate of N fertilizer and irrigation depth

Irrigation depth (cm)	N rate (kg ha^{-1})	Urea N uptake (kg ha^{-1}) Straw	Grain	Total	N recovery (%)	Ammonium nitrate N uptake (kg ha^{-1}) Straw	Grain	Total	N recovery (%)	Rate average N uptake	N recovery (%)
5	0	4.35	26.65	31.00	00.00	4.35	26.65	31.10	00.00	31.00	00.00
	100	11.82	54.86	66.68	35.68	10.48	50.53	61.01	30.01	63.84	32.85
	150	11.78	55.84	67.62	24.41	15.17	56.92	72.09	27.39	69.85	25.90
	200	17.64	62.29	79.93	24.47	18.14	64.52	82.66	25.83	81.29	25.15
	Average:	11.40	49.91	61.31	28.19	12.04	49.66	61.71	27.74	61.50	27.97
7.5	0	3.99	31.16	35.15	00.00	3.99	31.16	35.15	00.00	35.15	00.00
	100	10.42	54.67	65.09	29.94	10.27	55.10	65.37	30.22	65.23	30.08
	150	13.27	54.68	68.55	22.27	13.96	57.34	71.30	24.10	69.92	23.18
	200	15.32	54.78	70.10	17.48	15.24	61.57	76.81	20.83	73.45	19.15
	Average:	10.90	48.82	59.72	23.23	10.87	51.29	62.16	25.05	60.94	24.14
10	0	3.56	28.84	32.40	00.00	3.56	28.84	32.40	00.00	32.40	00.00
	100	10.04	45.93	55.97	23.57	11.72	55.70	67.42	35.02	61.69	29.30
	150	13.19	47.18	60.37	18.65	10.99	61.33	72.32	26.61	66.34	22.68
	200	16.44	57.47	73.91	20.76	12.26	78.10	90.36	28.98	82.13	24.87
	Average:	10.80	44.85	55.66	20.99	9.63	55.99	65.63	30.20	60.64	25.60
	Source average	11.03	47.86	58.89	24.14	10.85	52.31	63.16	27.66	61.03	25.90

N content v/s others	** 10.86	N source	N.S
N rate	** 8.87	Irrigation	N.S
** Significant at 0.01 Level	* Significant at 0.05 Level		N.S. Non-Significant

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