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NITROGEN USE EFFICIENCY IN WHEAT

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A field experiment with three sources of nitrogenous fertilizers (NH_4, NO_3, Urea) applied at 100 kg N/ha as broadcast, dibbled 10 cm deep and dibbled 10 cm deep mixed with poultry manure at 1 ton/ha between 25 cm part rows of wheat. Phosphorus at 90 kg P_2O_5 and potash at 60 kg K_2O/ha were applied as a basal dose. Grain and straw yields were improved significantly (5% level) due to the method of fertilizer application. Ammonium sulphate applied mixed with poultry manure proved best combination over other sources and methods of application. Total nitrogen uptake was maximum from ammonium sulphate followed by urea and nitrate forms where poultry manure was applied with these sources. To meet the crop requirements applied N was supplemented from soil N to a depth of 75 cm. It was concluded that wheat uptake of nitrogen was increased and used more efficiently with deep placement (dibbling) as compared to broadcasting.

Key words: Nitrogen, Efficiency, Wheat.

Introduction

The efficient use of applied N is not only influenced by the interaction of native soil nitrogen but also to various soil depths in the soil profile. In Pakistan, different sources of N fertilizers are available and applied indiscriminately as broadcast, and hence are subject to atmospheric losses due to calcareous nature and high pH of the soils. An effort was made to compare the applied N sources and their deep placement on the uptake of both applied and native soil nitrogen in the present studies.

The increased demand of N fertilizers for crop production, cost of natural gas and unstable nature of soil N are factors which contribute to the increasing cost of fertilizer nitrogen. It is, therefore, imperative to adopt effective ways and means to increase yield per unit of fertilizer used. Nitrate contamination of ground and surface water has encouraged an increasing number of investigations and from the data obtained earlier [1-3], it was assumed that high fertilizer use efficiency will permit high yields while minimizing pollution potential. Nitrogen use efficiency (NUE) depends on the method by which it is calculated. On the assumption that applied N had no effect on the uptake of native soil N [2] recommended that NUE be calculated from the difference between N uptake by fertilized and non-fertilized treatments. Plant available N was measured as described by Baethgen *et al.* [4] to determine the significance of soil N fractions to the plant available N supply and to predict N uptake by wheat. All soils provided significant amounts of N to the wheat. Onken *et al.* [5] measured nitrate N in soil samples taken from soil profile up to 90 cm. Regression analysis of the data indicated that residual soil N be counted as a separate variable with the applied N influencing corn yields. Fertilizer use efficiency (FUE) was greatly reduced due to residual N.

When N placed at five various depths from 30 to 150 cm was studied on winter wheat, N uptake tended to decrease with increasing depth of application [6,7] and used the technique of applying labelled N at various depths to show that wheat recovered more applied N from 45 cm depth than from 15 cm. The NUE was increased by applying ^{15}N labelled urea fertilizer to sorghum 5 cm deep banded and split placement over surface application or incorporation [8]. Maximum yield of winter wheat approached with 55 kg N/ha deep placed (60-120 cm) as compared to higher rates surface placed [9].

Poultry manure was compared with ammonium nitrate (AN) for yield, N uptake and residual soil N [10]. Soil N and N leaching were generally higher with AN than with poultry manure. Nitrogen uptake and corn grain yield were seldom significantly different. Excess N in soil was higher for poultry manure than for AN.

Nitrogen placement was measured by Sharma *et al.* [11]. Concentration of nitrate was high only in the upper soil layers. Total N uptake was greater with deep placed N than with N surface mixed. Therefore, main objectives were: (i) to study the effects of N sources and methods of application on yield and (ii) nitrogen use efficiency.

Materials and Methods

Three sources of N fertilizers were tested on wheat (Rawal-87) at Barani Agriculture Research and Development (BARD) Yard location, National Agricultural Research Centre, Islamabad. Soil of the selected land was tested before planting. Composite soil samples were collected with King tube. Soil samples with 15 cm increments from the surface were collected from 20 cores upto a depth of 150 cm. Samples were air dried in the laboratory, ground and passed through 2 mm sieve. Analyses for inorganic [NO_3, NH_4] and organic N, CEC, organic matter, available P, available K, $CaCO_3$, pH, and texture were carried out [12]. The experimental area (Rawal soil series) was fine silty hyperthermic, typic Ustochrept soil family [13].

The land was prepared by ploughing the field four times and moisture was conserved at 1/3 field capacity by providing dust mulching before wheat sowing. Sowing was done on Oct. 31, 1988 with automatic six-row seed drill with a seed rate of 100 kg/ha. Row-to-row distance was 25 cm and plot to plot distance was 50 cm. Plot size was 6 m^2. Fertilizer at N-100, P_2O_5-90 and K_2O-60 kg were applied per hectare. Check plots were provided only with P and K at 90 kg P_2O_5 and 60 kg K_2O per hectare respectively and incorporated. The design was a randomized complete block.

Sources of fertilizers were calculated on per plot basis and applied immediately after sowing in each plot. The amounts of NH_4-N, NO_3-N, urea-N, P_2O_5, K_2O and S were balanced from ammonium sulphate, diammonium phosphate, calcium nitrate, potassium nitrate, single supperphosphate and potassium sulphate. Nitrogen sources (NH_4, NO_3, Urea) were applied as broadcast as well as 10 cm deep holes (dibbling method), 15 cm apart between the rows for comparison with the farmers practice of broadcasting. One of the two dibbling treatments was also mixed with six months old poultry manure at 1 ton (10 kg available N) per hectare.

The experiment was maintained by hoeing and weeding during the growth period. Plants were sampled from each plot at harvest time on May 13, 1989 taking 15-20 tillers from the central four rows. Samples were cleaned off dust etc. with distilled water and oven-dried at 70°C for 48 hr. Grain samples were dried separately at the time of sampling. Plant material was ground with plant grinder and stored for analysis [12] in polyethylene bags. The amount of N uptake from different applied N sources was determined by deducting the N uptake of check treatment from the total N uptake (Table 4). Total organic N (Table 4) uptake was derived by multiplying total dry matter (grain and straw yield) with their respective organic N (Table 3). Nitrogen use efficiency (NUE) percent was estimated with the following formula:

$$NUE\% = \frac{\text{N uptake from available N} - \text{N uptake from check}}{\text{applied N}} \times 100$$

The crop was harvested on May 15. An area of 2m^2 was harvested from the central four rows. The weight of bundles was recorded after air-drying for a week. Grain weight was taken after threshing with automatic wheat sample thresher. Data were calculated on per hectare basis.

Results and Discussion

Wheat grain and straw yield. Variation in yield was significant due to fertilizer placement at 0.05 probability. Addition of poultry manure alongwith the N sources dibbled 10 cm deep was the best in case of ammonium sulphate and urea over other methods of application. Dibbling N sources without poultry manure yielded more than from broadcasting. Yield differences for nitrate N, however, were not significant. Dibbling of urea was more effective than broadcasting or its combined application with poultry manure. Although yield variation in case of poultry manure was not significant yet dibbling N was a better method over broadcasting which further improved yield with the addition of poultry manure in the case of ammonium sulphate source of fertilizer. Straw yield was also significantly increased at 0.05 probability due to nitrogen application as compared to check treatment. Vari-

TABLE 1. SOIL PROPERTIES OF EXPERIMENTAL SITE - BARD, NARC, ISLAMABAD.

Sample depth (cm)	CEC Me/ (100g)	P (ppm)	K (ppm)	Org.N (%)	Org.M (%)	$CaCO_3$ (%)	pH (1:1)
00-15	10.5	0.9	106	0.07	2.46	0.62	7.7
15-30	12.2	0.9	101	0.06	1.73	1.37	7.6
30-45	10.8	0.9	94	0.05	2.24	2.00	7.6
45-60	10.5	1.0	102	0.05	1.88	1.04	7.6
60-75	12.0	1.0	87	0.06	2.38	0.75	7.6
75-90	10.1	1.1	110	0.06	1.10	0.75	7.5
90-105	10.0	0.9	98	0.05	0.28	1.25	7.5
105-120	10.9	0.8	97	0.05	0.86	1.00	7.5
120-135	10.9	0.7	85	0.04	1.52	1.00	7.6
135-150	11.0	0.7	101	0.04	1.29	1.00	7.8

Soil = 0-15 cm depth - clay. loam = 15-150 cm depth - clayey.

TABLE 2. WHEAT GRAIN AND STRAW YIELD INFLUENCED BY N SOURCES AND METHODS OF APPLICATION.

Application method	N Sources					
	Grain yield (t/ha)			Straw yield (t/ha)		
	NH_4-N	NO_3-N	Urea-N	NH_4-N	NO_3-N	Urea-N
Check	4.77	4.77	4.77	7.16	7.16	7.16
Broadcast	5.31	5.59	5.49	8.83	9.06	9.07
10 cm deep	6.10	5.77	6.45	9.47	8.80	9.59
10 cm deep+ poultry manure	6.60	5.80	6.19	6.19	8.30	8.94

LSD at 5%. Grain = 0.92. Straw = 1.24.

ation in yield due to method of application was not found significant. Maximum straw yield was recorded from urea treatment followed by ammonium sulphate and nitrate. Fertilizer placed 10 cm deep in dibbles also produced more straw yield in case of urea and ammonium sulphate whereas broadcasting nitrate proved more effective in giving highest straw yield over other methods of fertilizer application.

Grain yield in case of NO_3-N form was improved with dibbling over broadcasting yet total dry matter production was slightly more in case of broadcasting over other methods. Performance of NO_3-N was poor as compared to NH_4 and urea forms of nitrogen.

Deep placement and side dressing was found to produce more grain and dry matter yield in the wheat by many workers [7-9,11] as compared to broadcast application of N.

Nitrogen uptake and nitrogen use efficiency. Grain and straw N increased with the applied N. Plant N concentration was maxi. under broadcast application from urea whereas high N concentration was found under dibbling of NO_3 alongwith poultry manure (Table 3). Maximum N uptake was estimated from ammonium sulphate under dibbling alongwith poultry manure followed by urea dibbled without poultry manure

TABLE 3. NITROGEN CONCENTRATION OF WHEAT STRAW AND GRAIN FOLLOWING DIFFERENT SOURCES AND METHODS OF FERTILIZER APPLICATION.

Method	Depth (cm)	Source: Ammonium	Nitrate	Urea
		Straw N %		
Check	–	0.23	0.23	0.23
Broadcast	Surface	0.31	0.37	0.41
Dibbling	10	0.33	0.30	0.34
Dibbling + poultry manure	10	0.35	0.37	0.33
		Grain N %		
Check	–	1.71	1.71	1.71
Broadcast	Surface	2.52	2.38	2.53
Dibbling	10	2.51	2.51	2.43
Dibbling + poultry manure	10	2.51	2.59	2.47

TABLE 4. TOTAL AND FERTILIZER N UPTAKE BY WHEAT.

Application method	Total N uptake (kg/ha) Source: NH_4-N	NO_3-N	Urea-N	Fertilizer derived N (NUE %) kg/ha Source: NH_4-N	NO_3-N	Urea-N
Check	97.2	97.2	97.2	–	–	–
Broadcast	171.3	176.4	175.7	74.1	79.2	78.5
10cm Dibble	186.2	171.8	187.4	89.0	74.5	90.2
10cm Dibble +poultry manure	189.4	179.4	180.8	92.2	82.2	83.6

(Table 4). Dibbling fertilizer alone and alongwith poultry manure improved N uptake by wheat in case of NH_4-N as well as urea. Uptake was better under broadcast from the NO_3 source of fertilizer. In general, N uptake was greater from fertilized treatments over control. The amount of fertilizer derived N used by the plant from the applied fertilizer/manure ranged between 74.01-92.20% (Table 4).

The amounts of soil available N at various soil depths (Table 5) have been derived from Table 1. The available soil N has shown reducing trend at lower depths. Dibbling fertilizer alone as well as alongwith poultry manure improved the estimated NUE over broadcast. The ammonium source was also used more efficiently followed by urea and then nitrate.

The average amount of N uptake on N source basis was nearly the same for NH_4 and urea and low for NO_3-N. These requirements were also within 63.5-65.8% N use efficiencies range from soil as well as applied N from a soil depth of 0-75 cm.

Being positively charged, the ammonium ion from ammonium sulphate is absorbed over the negative surfaces of the

TABLE 5. AMOUNTS OF SOIL NITROGEN PRESENT IN ITS WHEAT FIELD BEFORE PLANTING.

Soil depth (cm)	NO_3-N (kg/ha)	NH_4-N (kg/ha)	Estimated (kg/ha) Seasonal Min. N	Estimated (kg/ha) Available N
0-15	6.50	6.18	28.00	40.68
15-30	3.40	8.24	23.60	35.24
30-45	0.62	7.66	20.80	29.08
45-60	6.54	8.42	21.60	36.56
60-75	4.02	4.12	24.00	32.14
75-90	1.86	1.30	20.00	23.16
90-105	6.50	5.04	20.40	31.94
105-120	2.16	4.42	18.80	25.38
120-135	2.78	2.98	16.40	22.16
135-150	2.78	1.48	16.00	20.26

Min = Mineralized; Available N = NO_3 + NH_4 + Min. N; Seasonal Min. -N = 2% of org. N.

TABLE 6. NITROGEN USE EFFICIENCY UNDER DIFFERENT APPLICATION METHODS AND N SOURCES OF FERTILIZERS.

Soil depth (cm)	Estimated available soil - N	Application method (%): Check	Broad-cast	10cm deep	10cm + poultry manure	Sources (%): Ammonium	Nitrate	Urea
0-15	40.68	–	–	–	–	–	–	–
0-30	75.92	–	97.29	–	–	–	98.14	–
0-45	105.00	92.64	83.49	88.70	85.28	87.51	85.68	87.04
0-60	141.56	68.71	70.85	75.27	72.84	74.45	71.83	74.04
0-75	173.70	56.00	62.53	66.43	64.59	65.82	63.50	65.46
0-90	196.86	49.41	57.65	61.25	59.72	60.73	58.60	60.40

colloidal clay particles and help in slow release of N as compared to other sources.

Plant N uptake was interdependent on the available soil N and the amount of fertilizer N as indicated by NUE (Table 6) that soil available N has been used by the plant along with fertilizer N from lower depths in profile. The amounts of total N uptake by the crop (Table 4) show that the applied fertilizer N (100 kg/ha) was not sufficient even at the 100% N use efficiency level to meet the crop requirements. The soil available and mineralizable N supplemented the additional crop requirements from various soil depths. No restriction could be placed to the root zone in these studies, from where plant nitrogen requirements were met.

Estimated crop N requirements were not met from 0 to 15 cm plough layer (40.68 kg/ha) and 100 kg applied N, even on 100% N use efficiency basis by the crop, which were much less than the crop obtained from the soil. Under broadcast method the N uptake could be met at 97.3% N use efficiency of the applied fertilizer plus soil N at a depth of 0-30 cm. Such a high N use efficiency may not be possible. Similarly, the percent N use efficiency at 0-45 cm depths was also high enough for wheat crop. The N use efficiency estimated at 0-60 and 0-75 cm depths seemed to be in acceptable limits.

The findings of these studies confirmed the results reported by many authors [2,3,6,8,11] that higher N uptake by wheat and increased NUE were accompanied with deep placement of N. Predictable results in these studies also supported the findings of work carried elsewhere.

Conclusion

Dibbling N fertilizers have reduced soil contact and exposure to microbial activities and improved N uptake by the plants and wheat yield as compared to broadcasting. Ammonium sulphate applied mixed with poultry manure proved a better combination over other combinations of N sources and poultry manure.

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