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Effect of long term fertilizer application on nitrogen dynamics in soil under rice-wheat cropping system in a Mollisol

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ABSTRACT

The effect of long term fertilization on nitrogen dynamics in soil under rice-wheat cropping system was investigated for two consecutive years during 2013-14 and 2014-15 in a Mollisol of Tarai region. The experiment was conducted in randomized block design with eleven treatments and three replications. The data on different nitrogen fractions in soil estimated after both the crops revealed that nitrogen was dynamic in nature in soil and always changed from one form to other form through biochemical reactions. NH_4-N in soil was relatively more than NO_3-N. Application of fertilizer encouraged conversion of NH_4-N to NO_3-N through biochemical reactions which was reflected in fertilized plots over unfertilized ones. Ammonical-N, nitrate-N, total hydrolysable-N and amino sugar-N ranged from 15.9 to 26.4, 7.0 to 17.2, 482 to 689 and 24.1 to 74.6 mg kg^{-1}, in surface soil (0-15cm), respectively in both years. The surface soil showed higher values of all fractions of nitrogen viz., total, available, ammonical, nitrate, hydrolysable and amino sugar nitrogen as compared to soils of lower depths. The highest rice and wheat crop yields were obtained with application of 100% NPK+FYM, which were significantly more than the other treatments. The uptake of N by grain and straw of both the crops was maximum with 100% NPK+FYM treatment.

Key words: Long-term fertilizers, N fractions, rice-wheat cropping system.

INTRODUCTION

In India about 33 per cent rice and 42 per cent wheat is grown under rice-wheat cropping system. As per an estimate nearly 65 per cent of total fertilizers used in the country, are applied to rice and wheat crops (Yadav and Kumar, 2009). Rice and wheat are world's second most important cereals crops, contributing 45% of digestible energy and 30% of the total protein in the human diet, as well as a substantial contribution to feeding livestock. Both rice and wheat are exhaustive feeder crops and this double cropping system is heavily depleting the soil in its nutrient content. A rice- wheat sequence that yields 7 t ha^{-1} of rice and 5 t ha^{-1} of wheat removes more than 300 kg nitrogen, 30 kg phosphorus and 300 kg ha^{-1} of potassium from soil. Rice-wheat system, in fact, is now showing signs of fatigue and is no longer exhibiting increased production with increases in input use (Ladha *et al.,* 2000). Increase in fertilizer nutrient input, especially N fertilizer, has contributed significantly to the improvement of crop yields (Cassman *et al.,* 2003). To maximize grain yield, farmers often apply a higher amount of N fertilizer than required for maximum crop growth. The nitrogen in soil can generally be classified into inorganic and organic forms. The larger amount of nitrogen (95 to 99%) occurs in organic forms, which is not immediately available to crops. The inorganic forms NH_4-N and NO_3-N are commonly taken up by the plants. Available N in soils originates from fertilizer N additions and mineralization of organic N, including soil organic matter, crop residues, and organic wastes. Integrated use of organic manure and chemical fertilizers not only sustained higher crop yields, but also improves the nitrogen status as well properties of soil (Sharma, 2005).

The response of fertilizer application depends upon the nutrients status and availability in soil. The availability of nutrients is affected by their different forms and conversion in soil. The ecological conditions of soil increase or decrease the movement of nutrients from surface layer to the subsoil layer in soil profile. Thus nutrients dyanamism plays a great role in plants nutrition and soil fertility. A lot of work has been carried out on impact of fertilizer nutrients application on crop yields, but a systematic study is required to determine the actual dyanamics of nutrients in soil. Nitrogen being the most deficient nutrient in Indian soils, the present investigation was undertaken to study the effect of long term fertilizer application on nitrogen dynamics in soil under rice-wheat cropping system on a Mollisol.

MATERIALS AND METHODS

A study was conducted to assess the effect of NPK fertilizers on different fractions of nitrogen in soil at G.B. Pant University of Agriculture and Technology, Pantnagar during 2013-14 and 2014-15 in a long-term fertilizer experiment which is in operation since Kharif 1971. This experiment is being conducted with rice-wheat cropping system on Beni silty clay loam soil having pH 7.30, EC 0.35, dSm^{-1},organic carbon 14.8 g and available N, P and K of 392, 18 and 125 kg ha^{-1} , total P 206.17 mg kg^{-1} and total N 0.13%. Ten treatments comprisingT_1 : 50%NPK+Zn, T_2 : 100%NPK, T_3: 150%NPK,T_4:100%NPK+HW+Zn,T_5: 100%NPK +Zn, T_6 : 100%NP+Zn, T_7 : 100%N+Zn, T_8 : 100%NPK+FYM, T_9 : 100%NPK-S+Zn, T_{10} : Control, with three replications were evaluated in randomized block design in plots of 300 m^2. Soil samples from four soil depths (0-15, 15-30, 30-45 and 45-60 cm) were collected from experimental plots after completion of cropping sequence in both the years. Composite soil samples were processed and analyzed for various physico-chemical properties viz., pH, EC, organic carbon and different nitrogen fractions following standard methods. Available nitrogen in soil was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956)and total nitrogen by kjeldhal's method as described by Page *et al.,*(1982).Soil was digested for preparing neutralized soil hydrolysates, which were than analyzed for total hydrolysable-N (THN), ammonia-N (AMMN) and organic fractions of nitrogen, viz., amino acid-N (AAN), amino sugar-N (ASN), hydrolysable unknown-N (HUN) and non-hydrolysable-N (NHN) (Page *et al.,* 1982).The inorganic nitrogen fractions were estimated by adopting standard analytical methods outlined by Bremner (1965).

RESULTS AND DISCUSSION

Crop yields

The highest grain yield of rice and wheat was recorded with 100% NPK + FYM (Table 1), which was significantly higher than other treatments including control. This treatment also recorded the highest straw yield (45.23 and 48.30 q ha^{-1}) which was followed by 100% NPK + Zn, 100% NP + Zn and 100 NPK + HW + Zn treatments. The lowest grain yield of rice (13.27 q ha^{-1} and 11.73 q ha^{-1}) and wheat (11.90 q ha^{-1} and 11.73 q ha^{-1}) was recorded in control in both years respectively. Similarly, lowest straw yields (22.77 and 18.10 q ha^{-1}) of rice and wheat were also observed in control during both years respectively. All fertilizer treatments gave significantly higher crop yields as compared to control. Application of 100% NPK + Zn (T_5) produced significantly higher grain yields of rice and wheat as compared to yields observed with 100% NP + Zn (T_6) and 100% NPK - S + Zn (T_9). The treatment 100% NPK + Zn produced second highest grain yields 43.67 and 40.78 q ha^{-1} of rice and 41.20 and 40.13 q ha^{-1} of wheat in both years, respectively. The increase in crop yields might be ascribed to zinc addition in soil which prevents the Khaira disease infestation in rice and wheat both crops (Bhatt *et al.* 2016). Significantly higher straw yields were observed with T_4, T_5, T_6, T_8 and T_9 treatments as compared to 100%N (T_7) and 50%NPK+Zn (T_1). The increase in rice and wheat yields might be due to integrated use of organic and mineral fertilizers and balanced use of NPK fertilizers along with deficient micronutrients (Bhatt *et al.,* 2016). Treatments 50% NPK (T_1), 100% NPK (T_2) and 150% NPK (T_3) did not show much difference in grain yields of rice and wheat both from each other. These treatments gave significantly lower grain and straw yields as compared to 100% NPK + Zn treatment. Remarkable but non-significant increases in grain and straw yields were found with sulphur application as 100% NPK + Zn (T_5) as compared to without sulphur treatments 100% NPK – S + Zn (T_9). Indirect application of sulphur through single superphosphate is beneficial to crop (Bhatt *et al.,* 2016). About 8.20 and 10.35 % increase in grain yield of rice and 8.53 and 8.50 % increase in grain yields of wheat was found with 100% NPK + FYM @ 15.0 t ha^{-1} when compared with yield observed by 100% NPK + Zn treatment during both years respectively. The increase in yields might be ascribed due to beneficial impact of integrated use of mineral fertilizers along with organic manure. These results are in agreement with the findings of Bandyopadhyay *et al.,* (2010), Bhatt *et al.* (2016) and Sharma and Subehia (2014).

Table 1: Effect of fertilizer treatments on grain yield, straw yield and total nitrogen uptake of rice and wheat crop during 2013-14 and 2014-15

Treatments	Rice crop				Total nitrogen uptake (kg ha^{-1})		Wheat crop				Total nitrogen uptake (kg ha^{-1})	
	Grain yield (q ha^{-1})		Straw yield (q ha^{-1})				Grain yield (q ha^{-1})		Straw yield (q ha^{-1})			
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
$T_1$50% NPK + Zn	34.37	32.55	31.17	32.63	58.28	58.00	29.87	28.53	32.20	34.30	50.66	54.00
$T_2$100% NPK	36.67	36.90	36.03	38.03	73.86	76.33	32.93	33.03	41.50	38.90	67.80	68.67
$T_3$150% NPK	35.03	35.57	38.63	39.63	76.70	84.33	32.53	32.80	37.37	38.07	73.80	75.33
$T_4$100% NPK+H.W. + Zn	40.07	38.63	39.20	39.00	79.63	79.34	35.97	36.61	43.77	41.77	77.37	76.34
$T_5$100% NPK +Zn	43.67	40.78	41.63	41.63	89.33	85.00	41.20	40.13	45.77	43.50	85.85	83.66
$T_6$100% NP + Zn	41.17	38.98	39.23	40.57	81.22	75.66	34.30	33.48	37.47	37.10	69.46	68.66
$T_7$100% N + Zn	31.87	30.25	32.47	32.47	63.67	60.34	31.13	30.15	33.33	32.73	60.29	59.00
$T_8$100% NPK+FYM	51.87	51.13	45.23	48.30	110.21	111.67	49.73	48.63	48.57	51.03	105.19	110.33
T_9 100% NPK(-S) + Zn	40.00	37.60	37.10	39.17	75.78	76.00	36.67	36.03	36.17	37.27	68.05	70.67
T_{10} CONTROL	13.27	11.73	22.77	18.10	23.06	19.33	11.90	11.73	14.80	15.03	16.92	19.00
CD (5%)	4.81	5.38	4.81	4.83	11.47	12.24	4.05	5.16	4.97	4.61	11.65	8.93

Table 2: Effect of fertilizer treatments on soil available-N (kg ha^{-1}) and total-N (mg kg^{-1}) at different soil depths during 2013-14 and 2014-15

Treatments	2013-14				2014-15			
	Available N		Total N		Available N		Total N	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1 50% NPK + Zn	229	174	631	539	233	179	640	546
T_2 100% NPK	239	183	787	581	242	185	809	642
T_3 150% NPK	289	206	815	720	307	219	852	743
T_4 100% NPK + H.W. + Zn	284	188	868	610	244	187	876	624
T_5 100% NPK + Zn	252	189	850	613	235	174	857	605
T_6 100% NP + Zn	248	179	810	616	238	160	833	603
T_7 100% N + Zn	245	169	728	511	232	161	751	529
T_8 100% NPK + FYM	320	217	915	718	337	229	932	735
T_9 100% NPK-S + Zn	207	175	868	609	213	180	886	630
T_{10} Control	180	136	567	420	172	131	563	407
T_{11} Fallow	298	202	943	685	280	200	937	787
CD (5%)	30.20	17.49	69.12	64.81	38.95	32.69	71.74	82.00

Nitrogen uptake

Total uptake of N by rice and wheat due to different treatments ranged from 23.06 to 110.21 and 16.92 to 105.19 kg ha^{-1}during 2013-14 and 19.33 to 111.67 and 19.00 to 110.33 kg ha^{-1} during 2014-15 by grain and straw, respectively. The treatment 100% NPK + FYM removed the highest N followed by 100% NPK + Zn during both the years (Table 1). The lowest removal of N was recorded under control in both the years. All other fertilizer treatments were statistically at par with respect to total N uptake, except T_1, T_5, and T_8 treatments (Table 1). Maximum uptake of nitrogen by rice and wheat were observed with 100% NPK + FYM in both years. Significantly higher N uptake was recorded with all fertilizer treatments as compared to control. Treatments 100% NPK + Zn (T_5), 100% NP + Zn (T_6), 100% NPK – S + Zn (T_9) and 100% NPK + HW + Zn (T_4) were statistically at par for total nitrogen uptake by both the crops. The increase in N-uptake may be attributed to increase in crop yields and availability of nitrogen in soil with addition of nitrogenous fertilizers and organic manures as reported by Jaga *et al.* (2017).The lowest N uptake was found in control. Treatments of 50% NPK + Zn (T_1), 100% NPK (T_2), 150% NPK (T_3), 100% N + Zn (T_7) and 100% NPK – S + Zn (T_9) gave significantly lower nitrogen uptake as compared to 100% NPK + FYM (T_8) and 100% NPK + Zn (T_5) treatment during both the years. The lower uptake in these treatments was due to imbalance use of nutrients caused reduction in crop yields as reported by Singh and Nand Ram (2007).Under 100% NPK + Zn treatments, 89.33 kg ha^{-1} N was removed by rice and 85.85 kg ha^{-1} N by wheat during 2013-14, 85.00 kg ha^{-1} N by rice and 83.66 kg ha^{-1} N by wheat during 2014-15, respectively. Whereas, 100% NPK + FYM gave 20.88 kg ha^{-1} more N uptake for rice and 19.34 kg ha^{-1} more N for wheat in 2013-14 and by 26.67 kg ha^{-1} more for rice and 26.67 kg ha^{-1} more for wheat in 2014-15 over 100% NPK + Zn. Application of 100% NPK + Zn gave higher removal of N by 8.11 kg ha^{-1} by rice and 16.39 kg ha^{-1} by wheat during 2013-14 and 9.34 kg ha^{-1} in rice and 15.00 kg ha^{-1} in wheat during 2014-15 as compared with 100% NP + Zn. Similarly, 100% NP +Zn produced 17.55 and 15.32 kg ha^{-1} more N uptake by rice and 9.17 and 9.66 kg ha^{-1} more N uptake in wheat as compared to 100 % N + Zn. Imbalance use of fertilizers decreased the nitrogen uptake by crops (Sharma and Subehia 2014). Graded doses of NPK fertilizers i.e. 50, 100 and 150% NPK increased the total nitrogen uptake by crops and this increase was 35.22, 50.80 and 53.64 kg ha^{-1} by rice and 33.74, 50.88 and 56.88 kg ha^{-1} by wheat during 2013-14, respectively and 38.67, 57.00 and 65.00 kg ha^{-1} by rice and 35.00, 49.67 and 56.33 kg ha^{-1} by wheat during 2014-15, respectively. The reduction in nitrogen uptake due to decline in crops yields as well as decrease in amount of nitrogen addition in soil. These results are similar to the findings of Singh (2017).

Table 3: Effect of fertilizer treatments on soil ammonical-N and nitrate-N (mg kg^{-1}) at different soil depths during 2013-14 and 2014-15

Treatments	2013-14				2014-15			
	Ammonical nitrogen		Nitrate nitrogen		Ammonical nitrogen		Nitrate nitrogen	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1 50% NPK + Zn	20.82	17.91	13.99	8.25	22.23	18.11	12.00	10.28
T_2 100% NPK	23.41	19.00	14.09	12.25	24.15	19.33	14.50	13.30
T_3 150% NPK	24.90	20.86	16.34	15.71	27.18	21.66	18.10	17.48
T_4 100% NPK + H.W. + Zn	26.05	22.25	14.53	13.01	26.35	22.70	15.58	14.68
T_5 100% NPK + Zn	24.96	19.68	13.58	14.05	23.14	19.15	13.43	12.31
T_6 100% NP + Zn	20.98	18.24	12.71	10.51	21.08	19.87	10.87	8.58
T_7 100% N + Zn	20.73	16.05	13.58	9.00	21.25	18.56	11.68	8.48
T_8 100% NPK + FYM	26.42	22.88	17.29	15.85	26.75	23.04	16.60	14.96
T_9 100% NPK-S + Zn	23.25	19.33	11.83	13.38	20.14	20.50	10.56	12.18
T_{10} Control	15.90	13.12	7.00	6.34	16.23	13.51	7.21	6.37
T_{11} Fallow	24.47	20.15	10.48	8.63	25.36	20.47	12.60	10.50
CD (5%)	2.12	2.14	2.22	1.55	3.66	3.66	2.86	2.09

Nitrogen dynamics in soil

The data of nitrogen fractions (Table 2 to 4) indicated that top soil (0-15cm) had higher values of total nitrogen, ammonical-N (NH_4-N), nitrate-N (NO_3-N), total hydrolysable-N, amino sugar-N and available N as compared to deeper soil layers. This might be ascribed due to higher mineralization of organic matter and organic residues in surface soil layer as reported by Bhatt *et al.,* (2016) and Sharma and Subehia (2014).Maximum values of total nitrogen (915 and 932 mg kg^{-1}), ammonical - N (NH_4-N) (26.42 and 26.75 mg kg^{-1}), nitrate-N (NO_3-N) (17.29 and 16.60 mg kg^{-1}), total hydrolysable-N(689 and 684 mg kg^{-1}), amino sugar-N(74.66 and 76.66 mg kg^{-1}), and available N(320 and 337 kg ha^{-1}) were found with 100% NPK + FYM treatments in surface soil (0-15cm) during both the years. Significantly higher total nitrogen, ammonical - N (NH_4-N), nitrate-N (NO_3-N), total hydrolysable-N, amino sugar-N and available N were also recorded with 100%NPK+Zn (T_5), 150%NPK (T_3), 100%NP+Zn (T_6) and 100%NPK-S+Zn (T_9) as compared to 50%NPK+Zn and control at all soil depths during both the years.

Application of 100% NPK (T_2) and 150% NPK(T_3) resulted significantly higher values of ammonical-N (NH_4-N), nitrate-N (NO_3-N), total hydrolysable-N and amino sugar-N in soils of all depths than to 50% NPK + Zn(T_1) and control(T_{11}). Similarly, application of 100% NP + Zn(T_6) and 100% N + Zn (T_7) gave significantly lower ammonical - N (NH_4-N), nitrate - N (NO_3-N), total hydrolysable-N and amino sugar-N in soils of all depths in comparison to 100% NP + Zn treatment during both the years. This might be ascribed to lesser amount of nitrogen reduces the biochemical conversion of nitrogen in soil (Sekhon *et al.,* 2011).Available and total nitrogen contents in soil were significantly higher with 100% NPK + FYM (T_8), 150% NPK (T_3) and fallow soils (T_{12}) as compared to 100% NPK + Zn (T_5), 100% NP + Zn (T_6), 100% NPK (T_2) and 100% N + Zn (T_7) treatments. Lowest amount of available N and total N were found with control and 100% N + Zn (T_7) treatment. The highest total and available nitrogen was recorded with fallow at all soil depths during both the years. It might be due to lesser loss of nitrogen through drain as well as denitrification under uncultivated conditions as (Sekhon *et al.* 2011).

Table 4: Effect of fertilizer treatments on soil total hydrolysable-N and amino sugar-N (mg kg^{-1}) at different soil depths during 2013-14 and 2014-15

Treatments	2013-14				2014-15			
	Total hydrolysable-N		Amino sugar-N		Total hydrolysable-N		Amino sugar-N	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1 50% NPK + Zn	536	469	39.42	24.92	531	465	40.41	27.91
T_2 100% NPK	544	471	43.44	26.12	539	450	45.44	29.16
T_3 150% NPK	589	507	47.45	35.94	584	503	49.45	38.92
T_4 100% NPK + H.W. + Zn	553	477	50.16	38.15	548	474	52.16	41.15
T_5 100% NPK + Zn	665	508	67.66	44.92	660	504	69.68	47.92
T_6 100% NP + Zn	540	475	50.00	35.00	536	440	53.00	43.00
T_7 100% N + Zn	525	460	40.00	28.00	500	410	43.00	36.00
T_8 100% NPK + FYM	689	515	74.66	52.63	684	511	76.66	55.65
T_9 100% NPK-S + Zn	547	484	49.09	37.91	542	480	51.03	40.92
T_{10} Control	482	378	24.12	13.01	477	374	26.12	17.25
T_{11} Fallow	638	494	45.11	34.96	633	490	47.15	37.91
CD (5%)	17.87	14.55	5.80	4.75	18.69	18.02	3.48	2.63

It may be concluded from the results that application of NPK fertilizers along with organic manure encouraged the formation of more amino acid-N and amino sugar-N in comparison to conversion of ammonical - N (NH_4-N) and nitrate - N (NO_3-N) from applied fertilizer and organic manure nitrogen. Higher values of all fractions of nitrogen were in top soils as compared to deeper soil layers. Application of 150% NPK fertilizer increased all fractions of nitrogen in soil. Application of 100% NPK + 5.4 t ha^{-1} FYM (dry weight basis) gave highest productivity of rice and wheat followed by application of 100% NPK + Zn.

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