Nitrogen Dynamics in Rice under Rice-Wheat Cropping System at Khumaltar Condition

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Abstract

Nitrogen fertilization is a key input in increasing rice and other crop production in the world. Realizing the issue, nitrogen dynamics Lalitpur, Central Nepal was studied in long-term experiment under rice-wheat cropping system at rainfed lowland condition of Khumaltar. The first objective of the experiment was to assess the contribution of organic, inorganic and biological nitrogen fixation (BNF) for the better nitrogen cycling and utilization of added and residual nitrogen by crops. The second objective was to quantify the NO_3^--N and NH_4^+-N in puddled soil at different soil depths and growth stages of rice in rotation with rice based wheat-cropping pattern.The nitrogen (N) level was used 0, 50, and 100 kg N per ha. The NH_4^+-N and NO_3^--N dynamic in three soil depth (0-15, 15-30 and 30-60 cm) were monitored and crop performance evaluated in terms of grain and straw yield.The rice grain and straw yield were observed in the higher N-addition and incorporation of soybean stubble.The NO_3^--N and NH_4^+-N in the soil were also higher in the soybean incorporation treatment than in other treatments. Higher NH_4^+-N was absorbed at maximum tillering stage than after rice harvest.

Keywords: Biological nitrogen fixation (BNF), Long-term effect, NO_3^--N and NH_4^+-N dynamic, Organic and inorganic nitrogen, Soil depths

Introduction

Nitrogen, the most important nutrient in crop production, is added to the crop through biological and chemical means. About 80% nitrogen comprises in atmosphere, yet the supply of food for human being and other animals is limited by nitrogen than any other element. The nitrogen cycle has two sub-cycles. One sub-cycle consist of the addition of nitrogen to soil by fixation and loss by denitification.The other sub-cycle consist of cycling nitrogen within the soil involving mineralization, nitrification and immobilization. Nitrogen can also get lost from the soil by leaching and volatilization. The sustainability especially nitrogen (N) is an important concern. Rice based wheat cropping system is quite popular sequential in Nepal. The majority of the population live in mid-hills of Nepal, where rice *(Oryza sativa L.)*, wheat *(Triticum aestivum L)* and maize (*Zea maize*) are the major staple food crop.

The rice and wheat crops are typically grown sequentially in a rice-wheat cropping system. But the total productivity of the system is declining and production is either leveling off or decreasing in mid-hills regions. These trends are related to cropping intensification and mismanagement of plant nutrients particularly the nitrogen, in package of practices for crops. Present situation of stagnant or declining yield under rice based wheat cropping system with high levels of chemical N fertilization have raised concerns about the long term sustainability and possible adverse environmental impacts of this practice (Sing & Paroda 1994). The heavy use of industrial N fertilizer may result in nutrient imbalance.The availability of nitrate nitrogen (NO_3^--N) and ammonium nitrogen (NH_4^+-N) from synthesis of plant's nitrogenous constituents is of prime importance.The aspect of this experiment mostly concerns nitrogen cycling in rice-wheat cropping systems which plays a vital role by providing information on turnover and recycling rates of nutrients during wet land to dry land cropping cycles.Another aspect of this experiment is monitoring the status and dynamic of nitrogen during and after the rice-cropping period. Nitrate is expected to increase in dry, decrease in submergence soil condition and disappear upon flooding.

Most farmers in Nepal broadcast urea directly into the floodwater after two four weeks of rice transplanting. Several soil scientists research findings have indicated that the broadcasting urea into floodwater resulted in an average 30% recovery of fertilizer N by the rice crop in dry and wet seasons. Applying two third of the urea by broadcasting and incorporation before transplanting and the remainder at panicle initiation-called best split-increased recovery to 40%. Nitrogen in puddle soil is subjected to a varity of transformations that may affect its efficiency by rice. Ammonical sources are subjected to fixation by clay, losses by volatilization and de-nitrification. Nitrification and de-nitrification fraction can also occur in soils subjected to flooding and draining conditions. Ammonium-N accumulates during flooding. When the soils is drained NH_4^+-N is nitrified which is mobile form of nitrogen, it may be lost through leaching and flooding. Nitrogen management is an important and also complex process in increasing crop production.

The experiment represents a rainfed lowland of Khumaltar, Lalitpur for the better nitrogen management and cycling under rice-based wheat cropping pattern, nitrogen levels, crop residues, green manuring (soybean) and Farm Yard Manure (FYM) incorporated in long-term experiment.

Materials and Methods

Nitrogen dynamics was studied in rice-wheat cropping system under long-term soil fertility experiments at Khumaltar condition that lies in mid hills agro-ecological zones. The experiment was laid out in Agronomy Research Farm, Khumaltar with randomize complete block design (RCBD) and replicated four times with 11 treatments in rice based cropping system are as follow:

Treatment Combination

Treat. No.	N (kg per ha)	P_2O_5	K_2O
1	0	0	0
2	100	0	0
3	100	30	0
4	100	0	30
5	100	30	30
6	0	30	30
7	100	0	30
8	50	0	0(+15 cm stubble)
9	50	20	0
10	FYM 10 t ha^{-1}	0	0
11	Incorporation with green manure (Soybean)	0	0

Rice variety Chinung-242 was used for the long-term experiment. Twenty five days old rice seedling was transplanted on July 10, 1999. From individual treatment plot, depth-wise composite soil samples were collected from 0-15 cm, 15-30 cm and 30-60 cm of soil depths respectively. The experimental site falls under flood prone area. Soil sampling was done at the maximum tillering, flowering and physiological maturity stages of rice. The soil samples were kept in the icebox at the time of sampling and brought in the laboratory of Soil Science Division at Khumaltar. The inert materials such as stone, plant roots and leaves, etc. were removed from the soil samples before extraction. At the same time, distilled water was added in each soil samples to moisten the soil. After one hour of moistening, the soil sample was mixed thoroughly with hand. A semi liquid soil paste was prepared before extraction with 2 M KCl solution. The filtrate was analyzed for NO_3^--N and NH_4^+-N.

Nitrate-N into the aliquot was analyzed by stem distillation methods as described by Keeney and Bremner (1966). Exchangeable NH_4^+-N in aliquot was analyzed by stem distillation with MgO method by Bremner (1965).

Results and Discussion

Soil fertility and plant nutrition have played key role in sustaining increased agricultural productivity. Long-term experiment plays an important role in understanding the complex interaction involving plants soils, climate and management practices and their effects on crop productivity. In Nepal, farmers from different agricultural ecosystems have reported that the crop productivity has declined which could be attributed to inadequate supply and management of plant nutrition (Ali *et al.* 1993). To cope with these problems the Soil Fertility and Plant Nutrition Unit of Soil Science Division carried out the following research activities in the year 1999/2001.

The highest rice grain yield was recorded (7.7 t per ha) in balance application of N P_2O_5 K_2O_5 kg ha-1 (T5) and lowest grain was obtained in control (5.5 t per ha). Statistic analysis showed that all the treatments were not significantly difference as compared to the control. Excluding the control treatment, remaining treatments were non-significantly difference as compared to each other. In general observation, the grain yield was affected due to chemical fertilizer and organic manures (Table 1).

Similarly, the heighest fresh straw weight of rice was recorded in treatment number five. Straw yield in control plot was found to be significantly difference as compared to other treatments. Yield components like plant height, no of tiller and panicle length were not likely to be distinguished each other over the control (Ttable 1).

Table 1. Effect of organic and inorganic fertilizers on rice grain, straw, plant height, tiller number and penicle length at Khumaltar condition, 1999.

S. No.	N: P_2O_5: K_2O kg per ha	Grain yield (t kg ha)	Straw yield (t kg ha)	Plant height (cm.)	Tiller No. (per m)	Panicle length (cm.)
1	0: 0: 0	5.50a	7.68a	102.60a	230.00d	21.95a
2	100: 0: 0	7.08b	10.33bc	102.20a	182.50ab	22.10a
3	100: 30: 0:	7.07b	9.23ab	104.35a	184.00abc	22.15a
4	100:0:30	7.53b	9.63abc	101.80a	203.75a-d	22.00a
5	100:30:30	7.73b	11.95c	103.20a	206.00a-d	21.75a
6	0:30:30	7.10b	8.15ab	102.50a	187.25a-d	22.10a
7	100:0:30	7.13b	8.75ab	104.25a	165.00a	22.10a
8	50:0:0 (+15 cm. stubble)	6.88b	9.23ab	103.40a	174.25ab	22.60a
9	50: 20:0	7.48b	9.32ab	104.70a	202.75a-d	22.20a
10	FYM 10 t per ha	7.45b	9.68abc	103.25a	217.25bcd	22.05a
11	Incorporation with GM (Soybean)	7.27	9.65	105.40a	225.75cd	22.55a
Mean		7.11	9.42	103.39	198.02	22.13
CV %		9.3	16.2	3.2	13.2	4.00
F-test		3.20 **	2.20	<1	2.63*	<1
LSD (0.5)		0.95	2.97	4.83	37.77	1.28
SED		0.47	1.08	2.36	18.50	0.63

- In a column means with the same latter are not significantly different.

a. NH_4^+-N at different soil depth at maximum tillering stage of rice

The means for ammonium-N at different soil depth at maximum tillering stage of rice were compared and found that the amount of $NH4^+$-N in 15-30 cm soil depth showed slightly higher. The incorporation of soybean as a green manure treated plot (T11) extracted the highest amount of NH_4^+-N ions. The NH_4^+-N ion concentration in 0-15 cm soil depth of control plot was significantly lower compared to other treatments (Table 2).

Table 2. Means for ammonium-N (kg per ha) at different soil depth at maximum tillering stage of rice in long-term soil fertility experiment of Khumaltar, 1999

		Soil depth			
S. N.	N: P_2O_5: K_2O kg per ha	0-15 (cm)	15-30 (cm)	30-60 (cm)	Means
1	0: 0: 0	8.64 c	12.88 e	11.05 f	10.86
2	100: 0: 0	17.70 b	17.21 e	18.37 e	17.76
3	100: 30: 0:	15.83 b	14.60 e	15.97 ef	15.47
4	100:0:30	35.23 a	23.98 d	24.08 d	27.76
5	100:30:30	34.81 a	36.89 a	35.90 b	35.87
6	0:30:30	15.79 b	12.53 e	11.77 f	13.36
7	100:0:30	35.69 a	34.59 ab	27.56 cd	32.95
8	50:0:0 (+ 15 cm. stubble).	37.87 a	30.22 bc	27.69 cd	31.92
9	50: 20:0	16.81 a	26.59 cd	25.63 d	23.00
10	FYM 10 t per ha	35.99 b	34.03 ab	31.33 bc	33.78
11	Incorporation with GM (Soybean)	38.20 b	36.98 a	41.65 a	38.94
	Means	26.69	25.50	41.65	25.61

CV % = 14.3

F-test = 30.42*

LSD (0.5%) = 5.13

b. NO_3^--N at different soil depth at maximum tillering stage of rice

The trend of nitrate-N concentration in different soil depth indicated that when the soil depth increases the NO_3^--N concentration also increases at maximum tillering stage of rice. This is due to leaching of NO_3^--N ions in submergence condition in rice soil. The NO_3^--N ion concentration in each soil depth of control plot revealed that significantly lower as compared to other treatments (Table 3). The treatment means indicated that the higher amount of NO_3^--N was extracted from the application of balance fertilizers (T5) and soybean green manuring plot (T6).

Table 3. Means for nitrate-N (kg per ha) at different soil depth at maximum tillering stage of rice in long-term soil fertility experiment of Khumaltar, 1999

		Soil Depth			
S. N.	N: P_2O_5: K_2O kg per ha	0-15 (cm)	15-30 (cm)	30-60 (cm)	Means
1	0: 0: 0	3.78 e	6.25 c	6.98 d	5.67
2	100: 0: 0	10.18 c	15.88 ab	15.10 bc	13.72
3	100: 30: 0	14.12 b	15.83 ab	14.56 bc	14.70
4	100:0:30	12.08 bc	15.30 ab	16.23 bc	14.53
5	100:30:30	15.00 ab	18.50 a	20.08 a	17.86
6	0:30:30	7.00 d	15.60 ab	21.08 a	14.56
7	100:0:30	12.00 bc	13.58 b	15.88 bc	13.82
8	50:0:0 (+ 15 cm. stubble)	9.18c d	13.51 b	15.85 bc	12.85
9	50: 20:0	6.95 d	13.50 b	13.25 c	11.23
10	FYM 10 t per ha	12.00 bc	16.70 ab	16.88 b	15.19
11	Incorporation with GM (Soybean)	17.50 a	17.43 a	20.85 a	18.59
	Means	10.89	14.70	16.07	13.88

CV % = 14.66
F-test = 17.64 *
LSD (0.5%) = 2.85
S.E.D = 1.26

c. NH_4^+-N at different soil depth at flowering stage of rice

Extraction of NH_4^+-N from the soil of 15-30 cm and 30-60 cm depths at flowering stage of rice showed higher amount of concentration as compared to the 0-15 cm depth. Ammonium-N ion concentration in 0-15 cm and 15-30 cm soil depths in control plot were found to be significantly lower as compared to other treatments. Whereas, NH_4^+-N ions concentration in 30-60 cm depth of T1 and T6 was observed not significant of treatment effect (Table-4). In comparison of NH_4^+-N extracted at the physiological maturity stage of rice, the $NH4^+$-N extracted at the flowering stage was found slightly lower amount of NH_4^+-N. This is mainly due to variation of soil moisture content in field at sampling time.

Table 4. Means for ammonium-N (kg per ha) at different soil depth at flowering stage of rice in long-term soil fertility experiment of Khumaltar, 1999

		Soil Depth			
S. No.	N: P_2O_5: K_2O kg per ha	0-15 (cm)	15-30 (cm)	30-60 (cm)	Mean
1	0: 0: 0	4.08 e	12.90 g	13.82 e	10.13
2	100: 0: 0	12.50 d	14.21 g	15.93 e	14.21
3	100: 30: 0:	18.03 c	17.76 fg	29.21 bc	21.67
4	100:0:30	33.71 ab	20.27 ef	24.16 cd	26.05
5	100:30:30	37.86 d	28.20 cd	33.09 cd	33.05
6	0:30:30	11.53 d	13.98 g	10.75 b	12.09
7	100:0:30	29.36 b	30.30 c	27.45 e	29.04
8	50:0:0 (+ 15 cm. stubble)	33.81 ab	35.48 b	27.21 cd	32.17
9	50: 20:0	17.98 c	23.85 de	22.83 d	21.55
10	FYM 10 t per ha	31.00 b	41.38 a	29.06 bc	33.81
11	Incorporation with GM (Soybean)	34.06 ab	44.87 a	41.57a	40.17
	Means	23.99	25.71	25.01	24.90

CV % = 14.5
F-test = 32.91*
LSD (0.5%) = 5.05

d. NO_3^--N at different soil depth at flowering stage of rice

The nitrate-N concentration from the control plot was extracted significantly difference over the other treatments. NO_3^--N concentration was slightly higher at the flowering stage as compared to the maximum tillering stage of rice, due to drying of soil during soil sampling period. Slightly higher amount of NO_3^--N was extracted from 30-60 cm soil depth at this stage (Table 5).

Table 5. Mean for nitrate-N (kg per ha) at different soil depth at flowering stage of rice in long-term soil fertility experiment of Khumaltar, 1999

		Soil Depth			
S. No.	N: P_2O_5: K_2O kg per ha	0-15 (cm)	15-30 (cm)	30-60 (cm)	Means
1	0: 0: 0	4.88 e	4.83 d	5.07 a	4.92
2	100: 0: 0	15.18 cd	16.83 bc	19.65 a	17.09
3	100: 30: 0:	12.53 d	12.99 c	13.17 bc	12.90
4	100:0:30	20.95 ab	22.30 a	20.53 a	21.26
5	100:30:30	20.56 ab	16.29 bc	17.32 ab	18.06
6	0:30:30	20.56 ab	7.10 d	10.81 c	8.51
7	100:0:30	7.62 e	18.54 ab	20.82 a	18.77
8	50:0:0 (+ 15 cm. stubble)	16.97 ad	18.73 ab	17.21 ab	18.58
9	50: 20:0	19.79 abc	16.05 bc	16.76 ab	16.23
10	FYM 10 t per ha	15.88 bcd	15.00 bc	13.39 bc	15.15
11	Incorporation with GM (Soybean)	21.74 a	17.51 abc	18.26 ab	19.17
	Means	15.74	15.07	15.73	15.51

CV % = 21.7
F-test = 8.74**
LSD (0.5%) = 4.72

e. NH_4^+-N at different soil depth after rice harvest

As compared to soil depth means at different growth stages of rice indicated that the quantity of NH_4^+-N was observed decreasing trend when the growth stages of rice becomes older. Maximum NH_4^+-N was released at maximum tillering stage as compared to after rice harvest. The highest amount of NH_4^+-N was extracted after rice harvest from the balance fertilizer application plot (Table 6).

Table 6. Means for ammonium-N (kg per ha) at different soil depth after rice harvest in long-term soil fertility experiment of Khumaltar, 1999

		Soil Depth			
S. No.	N: P_2O_5: K_2O kg per ha	0-15 (cm)	15-30 (cm)	30-60 (cm)	Means
1	0: 0: 0	4.53 d	4.81 d	3.98 d	4.44
2	100: 0: 0	19.45 b	26.44 ab	26.69 ab	24.19
3	100: 30: 0:	27.77 a	28.21 ab	24.22 b	26.73
4	100:0:30	25.38 a	24.93 ab	26.47 ab	25.59
5	100:30:30	27.92 d	22.68 bc	27.06 ab	25.89
6	0:30:30	5.61 d	5.54 d	4.01 d	5.05
7	100:0:30	28.77 a	27.55 ab	25.61 ab	27.31
8	50:0:0 (+ 15 cm. stubble)	14.15 c	29.44 a	27.53 ab	23.71
9	50: 20:0	16.86b c	18.91 c	15.53 c	17.03
10	FYM 10 t per ha	27.30 a	27.93 ab	27.10 ab	27.44
11	Incorporation with GM (Soybean)	25.91 a	27.22 ab	31.18 a	28.10
	Mean	20.33	22.15	21.74	21.41

CV % = 6.4
F-test = 25.7*
LSD (0.5%) = 493

f. NO_3^--N at different soil depth after rice harvest

Principally NO_3^--N increases when the soil becomes aerated. Due to this reason, maximum nitrate-N was extracted after rice harvest as compared to NO_3^--N extracted in maximum tillering and flowering stages of rice. The NO_3^--N ion concentration in each growth stages of rice was found to be increasing when the soil depth increases. This is due to leaching of NO_3^--N ion in submergence condition of rice soil. The NO_3^--N ion was extracted higher amount in 30-60 cm soil depth after rice harvest (Table 7). Similar results were observed in rainfed lowland at Mariano Marcoss State University (MMSU), Batac, Illocas Norte, Philippines (Khadka, 1997). The soil sample from soybean green manure incorporated treatment (T11) extracted higher amount (31.4-kg per ha) of nitrate-N.

Table 7. Means for nitrate-N (kg per ha) at different soil depth after rice harvest in long-term soil fertility experiment of Khumaltar, 1999

		Soil Depth			
S. No.	N: P_2O_5: K_2O_5 kg per ha	0-15 (cm)	15-30 (cm)	30-60 (cm)	Means
1	0: 0: 0	22.32 b	23.71 c	21.22 b	22.42
2	100: 0: 0	25.15 ab	23.72 c	30.87 a	26.78
3	100: 30: 0:	26.98 ab	23.32 c	26.37 a	25.56
4	100:0:30	28.67 a	27.00 bc	29.69 a	28.45
5	100:30:30	25.48 ab	27.76a bc	27.46 a	26.90
6	0:30:30	16.34 c	16.91 d	14.46 c	15.90
7	100:0:30	22.45 b	26.72 bc	29.15 a	26.10
8	50:0:0 (+ 15 cm. stubble)	25.29 ab	31.98 a	27.86 a	28.38
9	50: 20:0	26.00 ab	27.15 bc	27.92 a	26.64
10	FYM 10 t per ha	26.09 ab	25.92 bc	27.92 a	26.64
11	Incorporation with GM (Soybean)	25.57 ab	29.34 ab	29.87 a	28.26
	Mean	24.58	25.77	26.61	25.65

CV % = 11.4
F-test = 7.42*
LSD (0.5%) = 4.11

Conclusion

The concentration of NH_4^+-N and NO_3^--N ions in soil were found in an increasing trend both in balance of fertilizer as well as combined application of organic and inorganic fertilizer treatments. In other hand, higher amount of NO_3^--N ions concentration was observed in the lower soil depth (30-60 cm) which may have been caused by leaching action of NO_3^--N ions during submergence condition.

Following recommendations are made on the basis of research finding

1. Residual effect of nitrogen fertilizer like NO_3^--N ions after rice can be utilized by succeeding dry season crop like wheat.
2. Nitrogenous fertilizer should be applied in split doses to increase maximum efficiency in both wet and dry season crops matching the N uptake time. Therefore, N losses can be minimized.
3. Organic manure helps maintain soil productivity in long-term basis and also helps to minimize the excess use of inorganic fertilizer. In other word, it will help produce sustainable agriculture production and also reduce environment pollution.
4. The deep-rooted plant like legume crops can be grown to utilize nitrate-N from the deeper soil horizons, which get lost from the plough layer by leaching process.

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