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Mineral and Labile Organic Nitrogen Fractions in Soil Profile and Their Response to FYM and Inorganic Fertilization in Different Growth Stages of Rice Crop

Babita Tamuli [a*], Devajit Bhattacharrya [b], K. N. Das [b] and Tapan Jyoti Ghose [c]

[a] Krishi Vigyan Kendra, Assam Agricultural University, Cachar-788025, Assam, India.
[b] Department of Soil Science, Assam Agricultural University, Jorhat-785013, Assam, India.
[c] Regional Agricultural Research Station, Assam Agricultural University, Jorhat-785630 Assam, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Nitrogen is the key element among the major nutrients in crop production. The mineralizable soil organic nitrogen is the main contributors of soil N supply. A better understanding of soil organic nitrogen dynamics in agro-ecosystems is needed to improve N management. The present investigation was conducted in Regional Agricultural Research Station (RARS), Assam Agricultural University, Titabar, Jorhat during 2017-18. In this study, the impact of Farmyard Manure (FYM) and inorganic fertilization on soil mineral nitrogen (NO_3^--N and NH_4^+-N) dynamics and labile organic

**Corresponding author: E-mail: babitatamuli@gmail.com;*

nitrogen fractions viz. microbial biomass N (MBN), particulate organic N (PON) and water-extractable organic N (WEON) at three growth stages of rice viz. active tillering, flowering and physiological maturity stages and nitrogen stock were assessed. Six treatments viz. control (no fertilization), 100% NPK, 100% NPK + FYM 5 t ha-1, 50% NPK, 50% NPK + 50% N through FYM and FYM 10 t ha-1 were tested in randomized block design with four replications. The results showed that NO3−-N and NH4+-N were found to be significantly higher in 100% NPK+FYM 5 t ha-1 at the three growth stages of rice. The labile organic nitrogen fractions were significantly higher in FYM 10 t ha-1. All these variables were decreased with increase in crop growth stages. Integrated use of inorganic fertilizer and FYM recorded the highest nitrogen stock. Stepwise regression analysis indicated that NH4+-N was the main contributor to nitrogen stocks at the three growth stages of rice of the studied soils.

Keywords: Mineral nitrogen; labile organic nitrogen fractions; N stock; rice growth stages; inorganic fertilizer; crop growth; microbial biomass.

1. INTRODUCTION

Of all the essential nutrients, nitrogen (N) has the most pronounced effect on plant growth and development. But most of the agricultural soils are deficient in this nutrient [1]. Since a bulk of total soil N is present in organic form, the quantity of inorganic N is usually small and easily depleted and hence cannot support plant growth for a long time. Soil organic nitrogen (SON) is the main contributors of soil N supply [2,3]. Short-term changes in total SON are difficult to detect, therefore it is partitioned into various pools of differing turnover rates [4]. There is a lack of knowledge concerning the involvement of the labile organic N pool in N cycle and its significance to soil N supply. The individual fractions of labile organic N *viz*., microbial biomass N (MBN), particulate organic N (PON) and water-extractable organic N (WEON) have not been studied in different agricultural systems, across soils and climatic conditions. Hence, a better understanding of their interrelationships, underlying mechanisms and N transformation through different fractions is needed. The study on various N fractions at crop growth stages has received less attention and little relevant information in paddy soil. Keeping this in view, the research was carried out with the objective to evaluate the impact of FYM and inorganic fertilizers on mineral N dynamics, labile organic N fractions and N stock during three growth stages of rice.

2. MATERIALS AND METHODS

The investigation was conducted at Regional Agricultural Research Station (RARS), Assam Agricultural University, Titabor, Jorhat in 2017-18 during *sali* season in an *Inceptisol.* The climatic condition of the region is characterized by a subtropical environment with hot humid summer and relatively dry and cool winter with an annual mean temperature of 24.5°C and a mean annual precipitation of 1,146 mm. The soil is sandy clay loam texture with organic carbon 1.1%, pH 5.4, CEC 12.5 cmol (p+) kg^{-1}, available N 495.0 kg ha^{-1}, P 22.2 kg ha^{-1} and K 112.0 kg ha^{-1} at initiation of the experiment. The rice variety Gitesh was used in the present investigation which is suitable for staggered planting in *sali* season of Assam with aged seedlings. Six treatments *viz*., control (no fertilization), 100% NPK, 100% NPK + FYM 5 t ha^{-1}, 50% NPK, 50% NPK + 50% N through FYM and FYM 10 t ha^{-1} were tested in Randomized Block Design with four replications. Inorganic NPK fertilizers were applied at the rate of 40 kg ha^{-1} N, 20 kg ha^{-1} P and 20 kg ha^{-1} K as urea, single super phosphate and muriate of potash, respectively. All fertilizers were applied as basal except urea, in which two thirds of urea was applied as basal fertilization and one third as top dressing. The available N, P and K in FYM was 0.45, 0.24 and 0.52%, respectively. Composite soil samples were collected from surface (0-20 cm) in three growth stages of rice *viz.* active tillering, flowering and physiological maturity stage. For determination of N stock, soil samples were collected after harvest of rice. The composite soil sample was divided into two parts. The first part of soil samples was processed (<0.25 mm sieve) for determination of mineral N (NO_3^--N and NH_4^+-N), PON and WEON and the other part was stored in refrigerator for MBN analysis. NO_3^--N and NH_4^+-N was estimated by Colorimetric methods outlined by Baruah and Barthakur [5]. The MBN was estimated by using chloroform fumigation extraction according to the method presented by Vance et al. [6]. The MBN was calculated as follows [7]:

Microbial biomass N (mg kg^{-1}) = EN/kEN

Where, EN = [(extractable N from fumigated soil) − (extractable N from non-fumigated soil)]; kEN = 0.54, represents the efficiency of extraction of MBN.

The PON was determined by the procedure outlined by Cambardella and Elliot [8]. The WEON was extracted using the method presented by Haney et al. [9]. Soil N stock was calculated after harvest of rice according to the method described by Ellert and Bettany [10].

N stock (Mg ha^{-1}) = ρb (g cm^{-3}) x total N (kg ha^{-1}) x soil depth (cm), Where, ρb = bulk density

All the observations were statistically analyzed by using the statistical methods described by Panse and Sukhatme [11].

3. RESULTS AND DISCUSSION

3.1 Mineral N Dynamics at Different Growth Stages of Rice under FYM and Inorganic Fertilization

Application of 100% NPK+FYM 5 t ha^{-1} recorded significantly the highest NO_3^--N and NH_4^+-N at the three growth stages of rice (Table 1). The increase in NO_3^--N and NH_4^+-N in integrated application of FYM 5 t ha^{-1} with 100% NPK might be attributed to the addition of higher amount of root biomass which enhanced the microbial activity and nitrification process [12,13,14].

The mineral N fractions of the soils decreased with development of the rice growth stages (Table 1). The decrease in NO_3^--N from active tillering to physiological maturity stage might be due to continuous N uptake by rice plant throughout the growing period [15,16]. The decrease in NH_4^+-N with development of the growth stages might be because of transformation of a large proportion of basal fertilizers into NH_4^+-N, but its uptake by rice plant was lower at the active tillering stage leading to higher NH_4^+-N content in the soils [17]. The decrease in NH_4^+-N with time might also be attributed to preferential uptake of NH_4^+-N by rice crop.

3.2 Labile Soil Organic N Fractions at Different Growth Stages of Rice under FYM and Inorganic Fertilization

The fractions of labile soil organic N *viz*., MBN, PON and WEON were found to be the highest under FYM 10 t ha^{-1} at the three growth stages of rice (Table 2). The organic manure FYM might have created a suitable condition for microbial growth as it is a good substratum for microbial activity. Many studies had reported that organic manures increased MBN of croplands and then increased MBN contributed to plant growth by enhancing the nutrient source and sink function [18,19]. The significant positive effect of FYM 10 t ha^{-1} in PON than other treatments might be due to increase of the root and microbial biomass which are the main sources of PON [20,21]. FYM might also contributed to the PON fraction in soil because of significant quantities of N in FYM were retained in soil particulate fractions [22]. The results of present investigation revealed that use of FYM 10 t ha^{-1} recorded the highest WEON at the three growth stages of rice. FYM could be used by soil microorganisms as a source of energy and be mineralized to inorganic N. Application of FYM could enhance soil microbial activity and organic matter decomposition and this might be attributed to higher WEON in the soils [23]. The lower WEON in the inorganic fertilization might be due the utilization of WEON by the microbial biomass at higher rates [24].

The MBN, PON and WEON were decreased with development of the rice growth stages (Table 2). The higher MBN at active tillering stage could be attributed to greater microbial activity caused by greater root exudation [25] and optimum moisture availability at this early stage of the crop [26]. This gradually declined when the crop was attained physiological maturity stage. Tamilselvi et al. [27] observed higher MBN during vegetative stage of maize that was declining till the crop harvest. PON is an important source for mineralizable N. With the development of crop growth stages, organic matter of the soils was decreasing and therefore, PON might trend to decrease towards the later growth stages of rice. The higher WEON at active tillering stage might be attributed to the fact that, this fraction of labile organic N could be utilized by soil microorganisms at very early stages of crop growth and immediately converted to inorganic N. As a result, mineral N was higher at the early growth stage of rice. With time, rice plant prefers to uptake mineral N and thereby, WEON decreased in the later crop growth stages.

3.3 Soil N Stock

The highest N stock was observed 2.05 Mg ha^{-1} in 100% NPK+ FYM 5 t ha^{-1} which was significantly higher than the other fertilization treatments (Table 3). Gami et al. [28] also reported significantly higher N stock in combined

Table 1. Mineral N dynamics at different growth stages of rice

Treatments	NO_3^--N (mg kg^{-1})			NH_4^+-N (mg kg^{-1})		
	Active tillering	Flowering	Physiological maturity	Active tillering	Flowering	Physiological maturity
Control (no fertilization)	6.11^f	5.26^f	4.37^f	12.96^f	11.44^f	10.24^e
100% NPK	9.85^d	8.48^d	7.18^d	16.83^d	16.03^d	15.26^c
100% NPK+ FYM 5 t ha^{-1}	15.26^a	13.47^a	12.28^a	22.13^a	21.23^a	20.17^a
50% NPK	8.16^e	6.20^e	6.08^e	14.35^e	13.47^e	12.11^d
50% NPK+ 50% (FYM) N	10.85^c	9.11^c	8.14^c	17.23^c	16.73^c	15.43^c
FYM 10 t ha^{-1}	13.81^b	11.02^b	10.87^b	20.09^b	19.15^b	18.08^b
SEm±	0.14	0.15	0.15	0.21	0.19	0.23
CD (P= 0.05)	0.39	0.43	0.39	0.61	0.52	0.64

Means in a same column followed by different letter (s) are significantly different at P≤0.05

Table 2. Labile soil organic N fractions at different growth stages of rice

Treatments	MBN (mg kg^{-1})			PON (g kg^{-1})			WEON (mg kg^{-1})		
	Active tillering	Flowering	Physiological maturity	Active tillering	Flowering	Physiological maturity	Active tillering	Flowering	Physiological maturity
Control (no fertilization)	17.64^f	16.97^f	15.64^f	0.23^f	0.19^f	0.17^e	6.65^f	5.99^f	4.90^e
100% NPK	22.95^d	21.55^d	20.97^d	0.67^d	0.59^d	0.53^c	10.74^d	9.95^d	8.97^c
100% NPK+ FYM 5 t ha^{-1}	26.30^b	25.91^b	24.56^b	0.97^b	0.92^b	0.90^a	11.95^b	11.46^b	10.58^a
50% NPK	20.16^e	19.76^e	18.94^e	0.27^e	0.24^e	0.23^d	7.59^e	6.70^e	5.88^d
50% NPK+ 50% (FYM) N	24.36^c	23.39^c	22.94^c	0.73^c	0.68^c	0.55^b	11.18^c	10.80^c	9.85^b
FYM 10 t ha^{-1}	28.87^a	28.13^a	27.67^a	0.99^a	0.94^a	0.90^a	12.50^a	11.94^a	10.90^a
SEm±	0.23	0.17	0.18	0.01	0.01	0.01	0.10	0.13	0.13
CD (P= 0.05)	0.65	0.49	0.52	0.04	0.03	0.02	0.28	0.37	0.37

Means in a same column followed by different letter (s) are significantly different at P≤0.05

Table 3. Soil N stock under FYM and inorganic fertilizer

Treatments	N stock (Mg ha^{-1})
Control (no fertilization)	1.22[f]
100% NPK	1.66[c]
100% NPK+ FYM 5 t ha^{-1}	2.05[a]
50% NPK	1.31[e]
50% NPK+ 50% (FYM) N	1.47[d]
FYM 10 t ha^{-1}	1.81[b]
SEm±	0.05
CD (P= 0.05)	0.14

Means in a same column followed by different letter (s) are significantly different at P≤0.05

Table 4. Multiple regression analysis of different N fractions with N stock

Parameter	Regression Equation	R^2
Active tillering stage		
N stock	= 0.199 + 0.080* NH_4^+-N	0.928
N stock	= 0.215 + 0.104* NH_4^+-N - 0.042* WEON	0.937
N stock	= 0.277 + 0.096* NH_4^+-N + 0.006* MBN -0.047 * WEON	0.942
N stock	= 0.343 + 0.033* NO_3^--N + 0.077* NH_4^+-N + 0.010* MBN - 0.067* WEON	0.945
N stock	= 0.338 + 0.036* NO_3^--N + 0.075* NH_4^+-N +0.011* MBN - 0.037* PON - 0.067* WEON	0.946
Flowering stage		
N stock	= 0.317 + 0.077* NH_4^+-N	0.922
N stock	= 0.345 + 0.103* NH_4^+-N - 0.048* WEON	0.935
N stock	= 0.381 + 0.097* NH_4^+-N + 0.004* MBN -0.049* WEON	0.937
N stock	= 0.398 + 0.014* NO_3^--N + 0.088* NH_4^+-N + 0.007* MBN - 0.056* WEON	0.938
N stock	= 0.402 + 0.012* NO_3^--N + 0.089* NH_4^+-N + 0.006* MBN + 0.0243* PON - 0.057* WEON	0.940
Physiological maturity stage		
N stock	= 0.361 + 0.079* NH_4^+-N	0.923
N stock	= 0.384 + 0.099* NH_4^+-N - 0.038* WEON	0.931
N stock	= 0.419 + 0.092* NH_4^+-N + 0.004* MBN -0.040* WEON	0.934
N stock	= 0.459 + 0.032* NO_3^--N + 0.078* NH_4^+-N	0.938
N stock	= 0.444 + 0.034* NO_3^--N + 0.078* NH_4^+-N + 0.012* MBN - 0.062* PON - 0.065* WEON	0.941

application of inorganic fertilizer and FYM than only inorganic NPK fertilized soils in Nepal.

3.4 Multiple Regression Analysis of Different N Fractions with N Stock

The contributions of different fractions of N, alone or in combination, towards the variability of N stock were computed using stepwise multiple regression analysis (Table 4). At active tillering stage, NH_4^+-N contributed 92.8% variation to N stock. All the fractions of N jointly contributed 94.6% variation to N stock. At flowering stage, NH_4^+-N contributed to 92.2% variation to N stock. The R^2 increased from 0.922 to 0.940 when other N fractions were added. NH_4^+-N contributed to 92.3% variation to N stock and R^2 was increased from 0.923 to 0.941 at physiological maturity stage. The other fractions of N contributed only 1.8% variation towards the N stock at this stage. Therefore, it is indicated that NH_4^+-N was the main contributor to the N stock at the three growth stages of rice.

4. CONCLUSION

From the above said findings, it can be concluded that the study on mineral N dynamics, labile soil organic N fractions and N stock under intensive cropping system enables optimal N fertilization management practice and improving N supplying capacity of the soils. The present findings indicated that NH_4^+-N has the major contribution towards N stocks of the studied soils.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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