Original Research Article

Mineraland labile organic nitrogenfractions in soil profile andtheir response to FYM and inorganic fertilization in different growth stages of rice crop

ABSTRACT

Nitrogen is the key element among the major nutrients in crop production. The mineralizable soil organic nitrogenis 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, Jorhatduring 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 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 tha^{-1}, 50% NPK, 50% NPK + 50% N through FYM and FYM 10 tha^{-1} were tested in randomized block design with four replications. The results showed that NO_3^--N and NH_4^+-Nwere found to be significantly higher in 100% NPK+FYM 5 t ha^{-1} at the three growth stages of rice. The labile organic nitrogen fractionswere significantly higher in FYM 10 t ha^{-1}.All these variables were decreased with increase in crop growth stages. Integrated use of inorganic fertilizer andFYM recorded the highest nitrogen stock. Stepwise regression analysisindicated that NH_4^+-Nwas the main contributor tonitrogen stocksat the three growth stages of rice ofthe studied soils.

Keywords: Mineral nitrogen; Labile organic nitrogen fractions; N stock; rice growth stages

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(Ayeni 2011).Since a bulk of total soilN is present in organic form, the quantity of inorganic N is usually small and easily depletedand hencecannot support plant growth for a long time.Soil organic nitrogen (SON) is the main contributors of soil N supply (Haynes 2005, Sharifi *et al.* 2008). Short-term changes in total SON are difficult to detect, therefore itis partitioned into various pools of differing turnover rates (Chen *et al*. 2018).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 oflabile 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 andinorganic fertilizerson mineral N dynamics, labile organic N fractions and N stock during threegrowth stages of rice.

2. MATERIALSAND 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 winterwith 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 Designwith four replications.InorganicNPK fertilizers were applied at the rate of 40 kg ha^{-1} N, 20kg 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 threegrowth 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 compositesoil sample was divided into two parts. The first part of soil samples wasprocessed(<0.25 mm sieve) for determination of mineral N (NO_3^--N and NH_4^+-N), PON and WEONand the other part was stored in refrigerator for MBNanalysis.NO_3^--N and NH_4^+-N was estimated by Colorimetric methods outlined by Baruah and Barthakur (1997).The MBNwas estimated by using chloroform fumigation extraction according to the method presented by Vance *et al.* (1987).The MBN was calculated as follows (Brookes *et al.* 1985):

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 (1992). The WEONwas extracted using the method presented by Haney *et al*. (2012). Soil N stock was calculated after harvest of riceaccording to the method described by Ellert and Bettany (1995).

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 (1989).

3. RESULTS ANDDISCUSSION

3.1 Mineral Ndynamicsat different growth stages of rice under FYM and inorganic fertilization

Application of 100% NPK+FYM 5tha^{-1} recorded significantly the highest NO_3^--N andNH_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 tha^{-1} with 100% NPK might be attributed to the addition of higher amount of root biomass which enhanced the microbial activity and nitrification process (Reddy *et al.*2003, Bharti2013, Rout *et al.*2017).

The mineral N fractions of the soils decreased with development of the rice growth stages(Table 1).The decrease in NO_3^--Nfrom active tillering to physiological maturity stage might be duetocontinuous N uptake by rice plant throughout the growing period (Meng *et al.* 2014, Manivannan and Sriramachandrasekharan 2016).The decrease inNH_4^+-Nwith development of thegrowth 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^+-Ncontent in the soils (Zhang *et al.*2009). The decrease inNH_4^+-N with time might also be attributed to preferential uptake of NH_4^+-Nby rice crop.

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

3.2 Labile soil organic N fractionsat different growth stages of rice under FYM and inorganic fertilization

The fractions of labile soil organic N *viz*., MBN,PON and WEONwere 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 MBNof croplands and then increased MBN contributed to plant growth by enhancing the nutrient source and sink function (Singh *et al*. 2007, Cerny *et al*.2008).The significant positive effect of FYM 10 t ha^{-1}in PON than othertreatments might be due to increase of the root and microbial biomass which are the main sources of PON (Manna *et al*. 2007, Naresh *et al*.2017). FYM might also contributed to the PON fraction in soil because of significant quantities of N in FYM were retained in soil particulate fractions (Whalen *et al*. 2003).The results of present investigation revealed that use of FYM 10 t ha^{-1}recordedthe 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 inthe soils (Chantigny 2003). The lower WEONin the inorganicfertilization might be due the utilization of WEON by the microbial biomass at higher rates (Whalen *et al*. 1999).

The MBN, PON and WEONwere 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(Aulakh *et al*. 2001)and optimum moisture availability at this early stage of the crop (Islam and Borthakur 2016). This gradually declined when the crop was attained physiological maturity stage.Tamilselvi *et al*. (2015)observed higher MBN during vegetative stage of maize that was declining till the crop harvest.PONis 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.

Table 2.Labile soil organic Nfractionsat 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

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*. (2009) also reported significantly higher N stock in combined application ofinorganic fertilizer and FYM than only inorganic NPK fertilized soils in Nepal.

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 $P \leq 0.05$

3.4Multiple 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 from0.922 to 0.940 when other N fractions were added. NH_4^+-N contributed to 92.3% variation to N stockand $R^2$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.

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

4. CONCLUSION

From the above said findings,it can be concluded thatthe 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^+-Nhas the majorcontribution towardsN stocks of the studied soils.

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