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Nitrogen mineralization from different manures under maize cultivation in acidic soils of Nagaland

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ABSTRACT

An experiment was conducted during the kharif season, 2016 at the experimental farm of SASRD, Nagaland University to study the nitrogen mineralization pattern due to application of manures viz. FYM, vermicompost (VC) and poultry manure (PM) at variable rates (2.5 and 5.0 t ha^{-1}) under field condition. Performance of the maize crop and nitrogen uptake was also studied at different growth stages. Seven treatments of manures at variable rates were evaluated with three replications in randomized block design. Manure quality in terms of nutrient content, C: N ratio, lignin content and lignin: nitrogen ratio exhibited significant impact on N-mineralization. N-mineralization from different manures recorded an increasing trend at different days after sowing of maize. However, immobilization of nitrogen was recorded in case of FYM and VC at both the rates at 15 days after sowing (DAS). In fact, immobilization was more with higher rates. At 90 DAS, significant difference in N-mineralization was observed with maximum amount of mineralized N in treatment T_7 (44.87 kg ha^{-1}) followed by T_6 (35.29 kg ha^{-1}), T_5 (18.10 kg ha^{-1}), T_4 (16.88 kg ha^{-1}), T_3 (12.76 kg ha^{-1}), and T_2 (12.07 kg ha^{-1}). Un-manured (Control) treatment recorded lowest amount of N-mineralized. PM at variable rates exhibited its superiority over FYM and VC in respect of total biomass yield and total N-uptake at different growth stages of maize. A highly significant correlation was observed among N-mineralization, grain yield and grain N-uptake irrespective of all the treatments. The present investigation revealed that the three different manures under study can contribute to the N- availability in soil at different growth stages differentially and hence, judicious management of manures in respect to time and rate of application can enhance maize productivity.

Key words: Maize, FYM, vermicompost, poultry manure, N-mineralization

INTRODUCTION

Maize (*Zea mays L.*) is one of the most important cereals, next to wheat and rice in respect to both area and production. In India, the area under maize cultivation is 8.69 M ha producing 21.81 Mt with a productivity of 2509 kg ha^{-1} (Anonymous, 2016). Maize is grown in all over the North Eastern states like Assam, Manipur, Arunachal Pradesh, Tripura, Mizoram and Nagaland. The state of Nagaland records an area of 89.4 thousand hectare under maize cultivation with 182.3 thousand tones production and 2039 kg ha^{-1} productivity (Anonymous, 2015-16). The negative effect of chemical fertilizers on soil health and fertility necessitates the utilization of resources available with farmers for crop production. Manure contains many nutrients that are needed for crop production. Of these, nitrogen is the most important one. It is hard to predict how much and when plant available nitrogen will be released from organic manure after application as some forms of nitrogen in the organic manure are not readily released. The majority of manure nitrogen is usually released in the first year of application but additional nitrogen become available in subsequent seasons. Plant available N of manure is highly dependent on manure composition, organic N fractions and appropriate timing, rate and method of application to crops. There is also report of positive correlation between initial nitrogen content of manures and total mineralized nitrogen from manures (Bordoloi, 2014). The most important concern pertinent to the efficient use of organic materials is whether their rates of nutrient release can be effectively managed or regulated to coincide with crop demand (Tilman *et al.,* 2002). In-appropriate management of manure could result in inadequate nitrogen supply or nitrogen surplus leading to nitrate losses to the environment (Mohanty *et al.,* 2011). In some instances, organic amendments can cause excess accumulation of NO_3-N in soil (Khalil *et al.,* 2005) with potentially detrimental effects on the environment. Conversely, if rates of N release are too slow, then crop yields may be

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constrained (Singh *et al.,* 2007). Further, more addition of organic matter resulted in an increase in pH of acidic soil (Vel Morgan, 2013). Judicious supply of nitrogen at critical growth stages of any crop is always a challenge to the crop growers. There should always be a synchrony between rate of N release from organic sources and crop demand. For obtaining such synchrony, knowledge based on N availability at a particular point of time from the applied organic source is very essential. The N supplying capacity of a certain soil layer could be characterized by N mineralization from organic matter which includes both native and exogenous organic matter applied as N source (Bordoloi, 2014). Studies on organic N mineralization in soils and manures have been undertaken in the past years, but majority has focused on impact of temperature, moisture, soil properties on N mineralization. Some studies have emphasized on the importance of manure composition such as fibre or fibrous C content, C: N ratio and lignin content, water-soluble C and volatile fatty acid in controlling soil N transformations after application (Griffin *et al.,* 2005; Azeez and Van Averbeke, 2010). Neglecting the effect of the factors such as manure types and their origin on N mineralization has led to wrong estimation of N availability to plants (Azeez and Van Averbeke, 2010). In the state of Nagaland, major sources of nitrogen to different crops happen to be organic. Ironically, no data base is available till today on pattern of nitrogen release from locally available organic manures, hence no scientific basis regarding doses as well as application time of organic N sources. Considering the importance of the release pattern of N from soil due to manure application to work out a synchrony between releases of nutrients with crop demands, the present study has been undertaken.

MATERIALS AND METHODS

The experiment was conducted in the Experimental Farm of School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema during *kharif* season of 2016. The geographical location of the experimental site was 25^0 45′ 43″ N latitude and 95^0 53′ 04″ E longitudes. The climate of the Medziphema area is subtropical with average annual rainfall 2000-2500 mm. The maximum and minimum temperature recorded during the period of investigation was 34.7°C and 20 °C, respectively, while maximum and minimum relative humidity was 94.0% and 52.0%, respectively. A total of 1233.9 mm of rainfall was received during the period of investigation. The soil of the experimental site was sandy clay loam in texture having pH 4.12 and 19.2 g kg^{-1} of organic carbon. Available N, P_2O_5 and K_2O were 200.1, 20.2 and 255.8 kg ha^{-1}, respectively. Maize variety 'RCM-76' was chosen as the test crop for the experiment. Seven treatments viz. T_1: Control, T_2; FYM @ 2.5 t ha^{-1}, T_3: FYM @ 5.0 t ha^{-1}, T_4: VC @ 2.5 t ha^{-1}, T_5: VC @ 5 t ha^{-1}, T_6: PM @ 2.5 t ha^{-1} and T_7: PM @ 5 t ha^{-1} was laid out in randomized block design. Well decomposed organic manures were applied as per treatments, whereas, the recommended doses of 60 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} were supplied through single superphosphate and muriate of potash, respectively. Representative plant samples were collected at 15, 30, 45, 60, 75, 90 DAS and at harvest (135 DAS). Samples were dried in oven and weight was recorded. The dry weight of samples was considered as biomass yield of crop and was expressed in q ha^{-1}. After recording biomass yield, the plant samples were analyzed for total N content at different DAS (Jackson, 1973). N-uptake by plants at different DAS and at harvest was calculated for each stages of growth. Soil samples (both initial and final) were analyzed for physicochemical parameters following standard procedures. Mineralized N-content was determined at periodic intervals in the samples collected at different DAS by 2M KCl extraction procedure described by Gianello and Bremmer, (1986).

The cumulative amount of N-mineralized from soil organic matter at time't' was calculated from the equation (1)

$$N_{(min)\ control} = Ni_{(control)t} - Ni_{(control)t=0} \quad (1)$$

The cumulative amount of N released from applied N source at time't' was calculated from equation (2)

$$N_{(rel)\ N\ source} = Ni_{(N\ treated\ soil)t} - Ni_{(control)t} - Ni_{(N\ source)} \quad (2)$$

Post harvest soil samples were analyzed for pH, EC, organic carbon and available N, P and K by adopting standard procedures. Mean data of each quantitative trait were statistically analyzed by the technique of analysis of variance. The significance difference was tested by ‘f’ test and difference between mean by using CD at 5% level (Gomez and Gomez, 1984).

RESULT AND DISCUSSION

Characterization of organic manures

pH of the different manures was of neutral range (6.84-7.30). Total carbon content of FYM was found maximum among the three organic sources used. Vermicompost and Poultry manures exhibited high total N content (1.44 and 2.00% respectively) and narrow C: N ratio (12.6:1 and 15.3:1) compared to FYM. Poultry manure exhibited least lignin content (15%) and lignin: nitrogen ratio (13.6:1). While vermicompost used in the experiment recorded high lignin content and lignin nitrogen ratio (48% and 33.3:1 respectively) among all the three manures used (Table 1). The superior quality of poultry manure denoted by high nitrogen content, lower C: N ratio, low lignin content and lower lignin: nitrogen ratio was also reported by Bordoloi, (2014).

Table 1: Chemical composition of organic manures used in the study

Manures	pH	Total C (%)	Total N (%)	C:N ratio	Total P (%)	Total K (%)	Lignin content (%)	Lignin: Nitrogen
FYM	7.30	38.0	0.86	44.2 :1	0.39	0.65	19.7	22.9 :1
Vermicompost	7.00	18.2	1.44	12.6 :1	1.00	1.55	48.0	33.3 :1
Poultry manure	6.84	30.7	2.00	15.3 :1	1.10	0.92	15.0	13.6 :1

Effect of manures on amount of N-mineralized

Application of FYM and vermicompost resulted in net negative mineralization or immobilization of N till 15 days after sowing (DAS) of maize, after which N-mineralization started picking up slowly and gradually (Table 2). In case of poultry manure no immobilization was recorded at 15 DAS. This is probably due to mineralization started few days after application of poultry manure in soils. At 45, 60, 75, 90 DAS and at harvest, N-mineralization due to application of poultry manure significantly increased compared to vermicompost followed by FYM application. Control treatment exhibited least amount of N-mineralized in all the stages of crop growth. Mineralization, however, decreased at harvest irrespective of the manures treatment. This result was in conformity with those of Bordoloi (2014). Greater amount of N-mineralization from the poultry manure may be credited to its superior quality in terms of nutrient content, low C: N ratio, lower lignin content and lignin: nitrogen ratio. Vermicompost although had the lowest C: N ratio (12.6: 1) and high N content (1.44%) released less nitrogen compared to application of poultry manure probably due to highest lignin content and wider lignin: nitrogen ratio. Kumar and Goh, (2003) reported that chemical composition of organic materials play a key role in their decomposition and nutrient release, which support the findings of present investigation. Similar observations on N-mineralization from various organic sources were also reported by Hertz *et al.* (2000). Higher values of lignin and lignin: nitrogen in FYM and vermicompost as recorded in the present study could be attributed to lower mineralization of N from these sources.

Table 2: N-mineralization (pattern) at different growth stages (Day after sowing) of maize as affected by manures

Treatment	Mineralized N (kg ha^{-1})						
	15 Days	30 Days	45Days	60 Days	75 Days	90 Days	135 Days
T_1 Control	0.46	0.40	4.70	8.06	9.40	9.44	4.48
T_2 FYM @ 2.5 t ha^{-1}	-6.71	1.18	5.15	8.75	11.42	12.07	9.54
T_3 FYM @ 5 t ha^{-1}	-13.40	0.88	6.50	10.71	12.76	12.76	9.69
T_4 VC @ 2.5 t ha^{-1}	-9.85	0.47	8.29	15.46	16.12	16.88	11.53
T_5 VC @ 5 t ha^{-1}	-15.23	1.30	6.72	15.90	17.80	18.10	14.55
T_6 PM @ 2.5 t ha^{-1}	4.48	12.36	20.83	26.54	30.11	35.29	23.07
T_7 PM @ 5 t ha^{-1}	4.36	17.29	33.60	38.77	40.55	44.87	37.18
SEm ±	0.31	0.08	0.26	0.26	0.26	0.26	0.14
CD (P=0.05)	1.11	0.29	0.93	0.94	0.94	0.94	0.51

Increased rate of N-mineralization was recorded with application rate 5 t ha^{-1} irrespective of manures compared to low application rate (2.5 t ha^{-1}) (Table 2). Application of poultry manure @ 5 t ha^{-1} recorded significantly higher rate of N-mineralization at 45, 60, 75, 90 DAS and at harvest compared to application of vermicompost and FYM at similar rates (Table 2). The result is in conformity to Bordoloi, (2014). It was also observed during the present study that degree of initial immobilization as recorded with FYM and vermicompost was tailored by application rates of organic sources at higher rates (5 t ha^{-1}) caused greater immobilization of nitrogen for FYM and vermicompost than their application at lower rates. The lability or resistance of the organic sources towards decomposition / mineralization seems to have played a role as observed in the present study. In case of more labile sources such as poultry manures, N-mineralization increase proportionately with their concentration. In contrast, increase in the concentration of more resistant sources *viz*. FYM and vermicompost, caused a decline in the amount of N mineralized there from. Similar effect of application rate of FYM on N-mineralization was reported by Mohanty *et al.,* (2010).

Dry matter yield and N uptake

Significant increase in dry matter accumulation by maize was evident due to application of poultry manure in different growth stages of the crop (Table 3). At harvest, maximum dry matter accumulation was recorded in treatment T_7 followed by T_6 (Table 3). The chemical composition of manures particularly N content, C: N ratio, lignin content and lignin: nitrogen ratio seems to have played crucial role in governing their effects on total dry matter yield of the crop. Among three organic manure studied, poultry manure with superior quality in respect to above chemical composition might have contributed more plant available N, which in turn resulted more dry matter accumulation/biomass yield by the crop. Similar findings were also reported by Bordoloi, (2014). On the other hand, VC although had low C:N ratio and high N content, remained poorest performer perhaps due to its considerably higher lignin content and lignin nitrogen ratio (Table 1). PM @ 5 t ha^{-1} recorded highest biomass N-content at different days after sowing compared to rest of the treatments. This is probably PM with superior quality might have contributed more plant available N in soil, which plant took up at a faster rate and increased the concentration of N in its tissues. Moreover, more rate of mineralization of N-in the same treatment can be credited to maximum concentration of this nutrient in the biomass. Similar trend in case of biomass N-uptake was also observed. Highest N-uptake was recorded in T_7 followed by T_6 in different growth stages (Table 3). Maximum biomass yield coupled with high biomass N-content in treatment T_7 might have resulted in more N-uptake. The positive effect of PM application on crop N uptake might be ascribed to timely availability of the nutrient. Nhahm (2003) reported that 60-70% of N in poultry manure is either in the forms of ammonia or uric acid, which are both rapidly available forms of N to plants. The greater availability of rapidly mineralized N in poultry manure is understood to have provided a significant boost to the plant uptake of the nutrient Moore *et al.,* (2010).

Table 3: Dry matter accumulation/Biomass yield (q ha^{-1}) and Biomass N-uptake (kg ha^{-1}) of maize at different growth stages as affected by manures

Treatments	15 Days		30 Days		45Days		60 Days		75 Days		90 Days		135 Days	
	Yield	Uptake	Yield	Uptake	Yield	Uptake	Yield	Uptake	Yield	Uptake	Yield	Uptake	Yield	Uptake
T_1	3.90	2.5	5.00	3.2	12.90	3.9	20.40	6.0	30.90	10.2	43.10	13.9	50.10	15.5
T_2	3.12	3.0	6.60	3.3	13.30	3.9	21.10	5.9	33.10	10.9	53.10	15.9	70.40	20.8
T_3	4.67	2.9	7.00	3.5	15.10	4.9	25.40	7.7	38.90	12.6	60.20	19.8	74.50	23.9
T_4	5.20	2.9	6.60	3.4	13.10	4.3	21.00	6.7	33.10	11.0	54.50	17.3	68.00	19.3
T_5	5.00	2.9	9.00	3.4	17.00	4.1	26.90	6.6	39.00	10.9	53.10	18.0	70.50	20.6
T_6	7.30	7.7	8.00	8.6	16.00	12.6	25.90	17.6	38.10	26.4	66.10	36.9	85.00	39.4
T_7	7.20	8.4	7.90	10.0	16.90	15.9	25.00	22.4	38.00	33.9	73.20	45.4	92.98	47.4
SEm ±	0.11	0.02	0.13	0.02	0.026	0.02	0.20	0.13	0.02	0.02	0.02	0.02	0.03	0.03
CD(P=0.05)	0.41	0.07	0.50	0.07	0.095	0.10	0.75	0.47	0.07	0.10	0.09	0.07	0.14	0.10

Maize grain yield, N content and N-uptake

Maximum grain yield (27.94 q ha^{-1}) was recorded in PM @ 5 t ha^{-1} followed by PM @ 2.5 t ha^{-1} (23.96 q ha^{-1}). Grain yield in vermicompost and FYM treatments was at par, whereas control treatment recorded lowest grain yield (10.9 q ha^{-1}). The per cent increase in yield in T_7 was 156.3% over control (T_1). Increase in grain yield along with more N content in grains in T_7 (PM @ 5 t ha^{-1}) treatment resulted significantly higher N-uptake by grain in the same treatment compared to rest of the treatments (Table 4). The superiority of poultry manure is causing greater increase in total N uptake has been reflected in the improvement in maize grain yield. These results are in agreement with Boateng *et al,* (2006). Improvement in grain yield might also be ascribed to better vegetative growth whereas resulted in better interception, absorption and utilization of radiation energy, leading to greater photosynthetic rate and finally more grain yield (Kaur *et al.,* 2008). The prominent impact of poultry manure on grain N uptake perhaps indicative of the prolonged and steady release of N from it even during the later crop growth stages that ensuring greater deposition of N in grains (Table 4). Lesser N-uptake by grains upon application of vermicompost and FYM might be ascribed to their inability to supply N in bio available form in amount and time synchronized with the crop demand Bordoloi, (2014).

Table 4: Grain yield (q ha^{-1}), grain N-content (%) and grain N-uptake (kg ha^{-1}) of maize as affected by application of manures

Treatment	Grain yield (q ha^{-1})	Grain N content (%)	Grain N uptake (kg ha^{-1})
T_1 Control	10.90	0.89	9.7
T_2 FYM @ 2.5 t ha^{-1}	12.40	0.99	12.4
T_3 FYM @ 5 t ha^{-1}	16.42	1.02	16.9
T_4 VC @ 2.5 t ha^{-1}	13.40	0.97	13.1
T_5 VC @ 5 t ha^{-1}	15.78	0.94	14.9
T_6 PM @ 2.5 t ha^{-1}	23.96	1.16	28.0
T_7 PM @ 5.0 t ha^{-1}	27.94	1.64	45.9
SEm ±	0.29	0.03	0.52
CD (P=0.05)	1.07	0.10	1.88

Correlation studies

A highly positive correlation was observed between nitrogen released with grain yield and grain nitrogen uptake (at harvest *i.e*. at 135 DAS) (Table 5) irrespective of manures applied. The positive correlation among all these parameters due to application of poultry manure probably because the manure brought about a greater synchrony between crop demand and availability of N. These results were inconformity to Sheoran *et al.,* (2015).

Table 5: Correlation between amount of N-released (at harvest), grain yield of maize and grain- N-uptake

	Amt of N released (at harvest)	Grain yield	Grain N uptake
Amt of N released (at harvest)	1		
Grain yield	0.95**	1	
Grain N uptake	0.98**	0.96**	1

****** *Significant at 1 % level* ***** *Significant at 5 % level*

Residual soil nutrients

Maintenance of greater residual soil nutrient availability (N, P, K) even after affecting higher crop N uptake was recorded with PM @ 5 t ha^{-1}. In fact, application of organic manures *viz*, FYM, vermicompost and poultry manure have improved the residual fertility status of soil which was evident from the more N, P, K, OC content in these treatments compared to initial content of these nutrients in soil. However, more amounts of nutrients got exhausted from the control treatment (Table 6).

Table 6: Residual soil nutrient availability as affected by application of manures

Treatments	pH (1:2.5)	OC ($g\ kg^{-1}$)	Av. N ($kg\ ha^{-1}$)	Av. P_2O_5 ($kg\ ha^{-1}$)	Av. K_2O ($kg\ ha^{-1}$)
T_1 Control	4.30	18.5	196.5	17.6	215.9
T_2 FYM @ 2.5 t ha^{-1}	4.93	20.0	215.3	25.5	272.3
T_3 FYM @ 5 t ha^{-1}	4.90	22.3	235.3	27.6	276.2
T_4 VC @ 2.5 t ha^{-1}	4.60	23.6	225.0	27.7	279.5
T_5 VC @ 5 t ha^{-1}	4.70	26.0	250.0	32.4	282.5
T_6 PM @ 2.5 t ha^{-1}	4.70	20.0	277.4	32.3	286.6
T_7 PM @ 5.0 t ha^{-1}	4.86	23.0	300.1	35.5	299.8
SEm ±	0.15	0.80	0.35	0.08	2.78
CD (P=0.05)	0.56	3.00	1.29	0.32	10.09
Initial value	4.12	19.2	200.1	20.2	255.8

From the findings of the present study, it can be concluded that organic manures follow a specific pattern of N-mineralization. Just after application up to 15 days, immobilization, instead of mineralization occurs due to application of vermicompost as well as FYM, probably because of their high lignin and lignin: nitrogen ratio. Whereas, N-mineralization started slowly and rate increased with time just after application of poultry manure. Initial immobilization is more when more amount of FYM or vermicompost is applied. From 30 days after application, mineralization shoots up till 90 days from all the organic manures studied and maximum amount of mineralized N recorded from poultry manures with higher rate (5 t ha^{-1}) of application. Slower release of nitrogen from FYM and vermicompost underlined the need for their much earlier application before sowing or transplanting (at least 25-30 days) and also initial supplementation of nutrient through labile sources. Poultry manure hold promise to be a labile source of nutrients which can affect N-release, crop growth and yield in a positive way. Application of poultry manure @ 2.5 t ha^{-1} or 5 t ha^{-1} can also supplement residual soil fertility in a greater way in the production of maize (*Zea mays* L). Further studies on different crops can be made in respect to nitrogen release pattern of different manures to check the veracity of the performance of poultry manures and others.

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