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Full Length Article

Influence of Organic Matter on Nitrogen Mineralization Pattern in Soils under Different Moisture Regimes

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Abstract

Application of organic residues returns mineral nutrients to the soil. The conversion of organic N, P and S to available forms occurs through the activity of microorganisms and is influenced by those factors (temperature, moisture, pH etc.) affecting microbial activity. A study was made to examine the mineralization pattern of nitrogen (N) from different sources of organic matter. Mineralization was studied by an incubation experiment with farmyard manure, dhaincha (*Sesbania aculeata*) and mungbean residues applied at two rates (2.5 and 5 t ha^{-1}) under two moisture levels (saturated and field capacity condition) over 12 weeks of incubation at 30°C in an artificial incubation room at Bangladesh Institute of Nuclear Agriculture (BINA). Soils from Bangladesh Agricultural University (BAU) farm, Mymensingh and On-Farm Research Division (OFRD) farm, Rangpur were used. The release of N with the amended soils increased progressively and attained a peak within 4 to 7 weeks of incubation for both the moisture regimes. The maximum amount of 64–91% N was released depending on the types of manure, rates of application and moisture level. In both soils, mineralization potential of N was higher under saturated soil condition. Mineralization of N was influenced by incubation period, rate of organic materials application, moisture regime and type of soil. So, before using different sources of organic manures and crop residues in the field due consideration should be given on their mineralization and nutrient release pattern of those organic materials.

Keywords: Nutrient release and balance; Moisture regime; Organic residue; Soil fertility

Introduction

Mineralization indicates the conversion of an element from organic form to inorganic form as a result of microbial decomposition. Soil organic matter increases with manure application. Soil organic matter undergoes mineralization and releases substantial quantities of N, P, S and smaller amount of micronutrients. Soil organic carbon (SOC) is importance to maintaining soil fertility and sustaining the productivity of agro ecosystems (Su *et al.*, 2006). SOC is also the source and sink of atmospheric CO_2 and plays a key role in global C cycling. Therefore, keeping a satisfactory level of SOC is significant for ensuring food security and mitigating climate warming (Lou *et al.*, 2011). Response of crops to applied fertilizer depends on soil organic matter. The quantity of soil organic matter depends on the quantity of organic materials which can be introduced into the soil either by natural returns through roots, stubbles, sloughed-off root nodules and root exudates or by artificial application in the form of organic manure which can otherwise be called organic fertilizer. Nutrients contained in organic manures are released more slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect. Complementary use of organic manure and mineral fertilizers has been proved to be a sound soil fertility management strategy in many countries of the world (Ayoola and Makinde, 2007). Organic matter mineralization was influenced by soil type, the sandy soil favoured more the N and C mineralization processes than the clayey loam and loam soils (Khalil *et al.,* 2001). Mineralization of nutrients from an organic amendment depends on biotic (Rowell *et al*., 2001) and abiotic factors (Nakhone and Tabatabai, 2008). The N mineralization-immobilization turnover was influenced by the type of soil and residue used (De Neve *et al.,* 2004). The N mineralization occurred after raising the pH of acid soils and N transformations depended on the types of substrates and moisture regime (Duhan *et al.,* 2001). In general, the optimum moisture for mineralization ranges from 65 to 100% of field capacity. Easily decomposable part of the soil organic matter undergoes quick mineralization and becomes a part of soil humus. The saturated conditions favored the accumulation of NO_3^--N contents, while submergence increased NH_4^+-N in the soil (Duhan *et al.,* 2005). The NH_4^+-N content in soil

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increased up to one week of incubation and then declined thereafter (Das and Puste, 2002). The NO_3^--N content in soil increased after first week of incubation but increase was relatively higher between 5th and 7th week of incubation and it became stable onwards. The amounts of NH_4^+-N and NO_3^--N, increased up to 60 days of soil submergence and increased further with the increased (1% by weight of soil) organic residue application (Dinesh and Dubey, 1999). The total N mineralized (mean 66%) were more than twice than that of net N mineralized (mean 29%). The net N mineralization was significantly higher in soils amended with organic manures compared to the unamended control (Singh and Mondal, 2000). In waterlogged soils, the maximum amount of N was mineralized during the period between 28 and 42 days of incubation (Keeney and Nelson, 1982). Soil organic matter of Bangladesh soils is declining with time due to intensive cropping, use of higher doses of chemical fertilizers with little or no use of animal manure, crop residues, compost and other organic materials. In addition, under humid tropic climate as in Bangladesh, mineralization of soil organic matter is rapid. Most of the work on N mineralization relates to either unamended or organic manure amended well aerated soils. However, information on decomposition and N mineralization of green manures under water-logged conditions is limited and inconclusive. In view of the foregoing considerations, the present study was undertaken to examine the N mineralization patterns of farmyard manure (FYM), dhaincha green manure (DH) and mungbean residue (MBR) for which period is the best for their nutrient release as well as ultimate supplement the nutrient needs of a crop.

Materials and Methods

The mineralization pattern of N from FYM, DH and MBR at two soil moisture conditions was investigated in the artificial incubation chamber under controlled temperature condition at Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh. Composite soil samples at 0–15 cm depth were collected from Bangladesh Agricultural University (BAU) farm, Mymensingh and On-Farm Research Division (OFRD) farm, Bangladesh Agricultural Research Institute (BARI), Rangpur. The BAU farm belongs to the Old Brahmaputra Floodplain, Agro-ecological Zone (AEZ)-9 and the OFRD farm to the Tista Meander Floodplain (AEZ 3). The morphological, physical and chemical characteristics of the soils are shown in Tables 1 and 2. The experiment was initiated in November 2006 and continued up to February 2007. The experiment was laid out in three factors complete randomized design (CRD) with three replications. The factors were soil (AEZ-9 and AEZ-3), moisture level (saturated and field capacity condition) and organic materials (FYM, dhaincha and mungbean residues), which were commonly used or in situ cultivation by the farmer's of Bangladesh. The chemical composition of different manures is given in Table 3. Altogether there were 16 (sixteen) treatments [2 × 2 × 3 + 4 control (two moisture level for each soil)]. An amount of 100 g air dry soil was weighed into a series of plastic containers. Four hundred and eighty (480) plastic containers used during the whole incubation period. The soil was thoroughly mixed with oven dry finely ground FYM, DH and MBR @ 2.5 and 5 t ha^{-1}. Moisture content of the soil was adjusted to maintain saturated (32–35% moisture) and field capacity (22–25% moisture) condition depend on soil used. The plastic containers were incubated up to 12 weeks at 30^{o}C temperature. Each container was covered with a sheet of aluminum foil to prevent rapid loss of water due to evaporation. The containers were weighed at every alternate days and the weight loss was supplemented by distilled water. Soil samples were collected periodically at one week intervals up to eight weeks and two week intervals for the rest period and analyzed for available N. A set of samples were withdrawn at each sampling dates, through destructive samplings. The data were corrected for moisture content and expressed on oven dry weight basis. For available N (NH_4^+-N and NO_3^--N) content soil was extracted by 2M KCl solution at 1:10 soil-extractant ratio. The aliquot was steam distilled with MgO and Devarda alloy to determine for available N (Keeney and Nelson, 1982). Mineralization potential (N_0) and rate constant (k_n) for different sources of organic materials were calculated by following an exponential equation (Sihag and Singh, 1999). The equation for N was $N_t = N_0$ $(1\text{-}e^{-kt})$, where N_t is the net nitrogen mineralized at time t, N_0 is the nitrogen mineralization potential and k is the rate constant.

Results

Mineralization of organic nitrogen from manure and crop residues into available N ($NH_4^+ + NO_3^-$) varied depending on soil moisture and incubation period. The N mineralizations from manure and crop residues for both the soils were initially very low. Mineralization was increased with the increase of incubation period up to 7 weeks of incubation and there after it declined with time (Figs. 1 and 2). In both the soils, the mineralization of organic N was slightly higher at field capacity compared to saturated condition. As expected the higher rate of manure and crop residues application (5 t ha^{-1}) produced higher amount of available N in soils compared to the lower rate (2.5 t ha^{-1}). The amount of available N was the highest in *Sesbania* amended soil followed by mungbean residue and farmyard manure application (Table 4). Nitrogen release pattern from both amended and unamended soils showed similar trend, however the magnitude of mineralization was lower in unamended soils. Among the amendments, the *Sesbania* amended soils had higher mineralization compared to farmyard manure and mungbean residue (Figs. 1 and 2). The net N-mineralization pattern was calculated by subtracting the amount of N released in amended soil and control (Fig. 3). The higher rate (5 t ha^{-1}) of manure and

Table 1: Morphological characteristics of the soil under study

Characteristics	BAU farm, Mymensingh	OFRD farm, Rangpur
Geographic position	24.75° N Latitude 90.5° E Longtitude	25.35° N Latitude 89.25° E Longtitude
Agro-ecological Zone (UNDP and FAO, 1988)	Old Brahmaputra Floodplain (AEZ 9)	Tista Meander Floodplain (AEZ 3)
General soil type	Non-Calcareous Dark Grey Floodplain Soil	Non-Calcareous Dark Grey Floodplain Soil
Taxonomic soil classification		
Order	Inceptisol	Inceptisol
Sub order	Aquept	Aquept
Great group	Haplaquept	Endoaquept
Sub group	Aeric Haplaquept	Typic Endoaquept
Soil series	Sonatala	Gangachara
Parent material	Brahmaputra river borne deposits	Tista river borne deposits

Table 2: Physical and chemical characteristics of the soils

Characteristics	BAU farm, Mymensingh	OFRD farm, Rangpur
Mechanical fractions (USDA system)		
Sand (0.2-0.02) mm %	31.0	31.2
Silt (0.02-0.002 mm) %	50.0	52.8
Clay (<0.002mm) %	19.0	16.0
Textural class	Silt loam	Silt loam
Bulk density (g cm^{-3})	1.45	1.26
Water holding capacity	55.5	48.5
Organic matter (%)	1.51	1.59
Cation exchange capacity (cmol kg^{-1})	12.2	9.5
pH	7.1	5.5
Total N (%)	0.078	0.085
Exchangeable K (cmol kg^{-1})	0.082	0.101
Available P (mg kg^{-1})	3.30	15.7
Available S (mg kg^{-1})	8.50	9.50

Table 3: Chemical composition of different manures

Manure	C (%)	N (%)	P (%)	K (%)	S (%)	C:N	C:P	C:K	C:S
Farmyard manure	32	1.45	0.39	1.55	0.23	22	82	21	193
Dhaincha (*Sesbania aculeata*)	43	1.76	0.35	1.27	0.22	24	123	34	195
Mungbean residue (*Vigna radiata*)	40	1.55	0.36	1.40	0.26	26	111	29	154

Table 4: Maximum release of available nitrogen from different sources of organic manure and crop residues after 5 to 7 weeks of incubation

Organic manure/crop residue	BAU farm soil, Mymensingh							
	Added to soil (mg kg^{-1})				Released (mg kg^{-1})			
	Saturated condition		Field capacity		Saturated condition		Field capacity	
	2.5 t ha^{-1}	5 t ha^{-1}	2.5 t ha^{-1}	5 t ha^{-1}	2.5 t ha^{-1}	5 t ha^{-1}	2.5 t ha^{-1}	5 t ha^{-1}
Farmyard manure	18.1	36.2	18.1	36.2	14 (77)	24 (66)	15 (83)	25 (69)
Dhaincha (*Sesbania*)	22.0	44.0	22.0	44.0	18 (82)	33 (75)	18.5 (84)	32 (73)
Mungbean residue	19.4	38.8	19.4	38.8	15 (77)	27 (70)	16.5 (85)	27 (70)
	OFRD farm soil, Rangpur							
Farmyard manure	18.1	36.2	18.1	36.2	13 (72)	23 (64)	15 (83)	25 (69)
Dhaincha (*Sesbania*)	22.0	44.0	22.0	44.0	17.5 (80)	29 (66)	20 (91)	32 (73)
Mungbean residue	19.4	38.8	19.4	38.8	13.5 (70)	25 (64)	17 (88)	29 (75)

Figures in parenthesis indicate per cent release of the added nutrients from different organic sources

crop residue application showed higher net N-mineralization compared to the lower rate (2.5 t ha^{-1}) in both the soils and moisture conditions (Table 4). The net N-mineralization was relatively higher when the soils were incubated at field capacity. For BAU farm soil, amended with 5 t ha^{-1} organic material, the net N-mineralization under saturated condition were 24 mg kg^{-1} (66% of added N), 27 mg kg^{-1} (70% of added N) and 33 mg kg^{-1} (75% of added N) due to incorporation of farmyard manure, mungbean residues and *Sesbania*, respectively (Table 4). On the other hand, at field capacity, the net N-mineralization was 25 mg kg^{-1} (69% of added N) with farmyard manure, 27 mg kg^{-1} (70% of added N) with mungbean residues and 32 mg kg^{-1} (73% of added N) due to *Sesbania* incorporation for the rate of 5 t ha^{-1} application. Similar trend of net N-mineralization was observed when the soils were amended with 2.5 t ha^{-1} either manure or crop residues, although the magnitude was different.

In OFRD farm soils, amended with 5 t ha^{-1} manure and crop residue, the net N-mineralization was 23 mg kg^{-1} (64% of added N) with farmyard manure, 25 mg kg^{-1} (64%

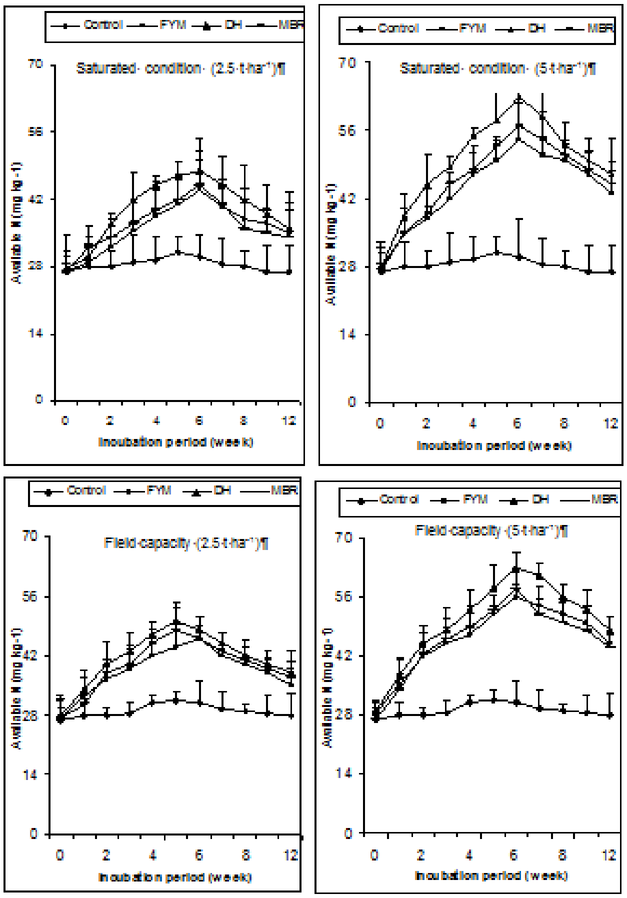

Fig. 1: Available N release pattern at BAU farm soil amended with manure, crop residues at two different rates and moisture regimes Vertical bars represent SE (±)
FYM = Farmyard manure, DH = Dhaincha, MBR = Mungbean residue

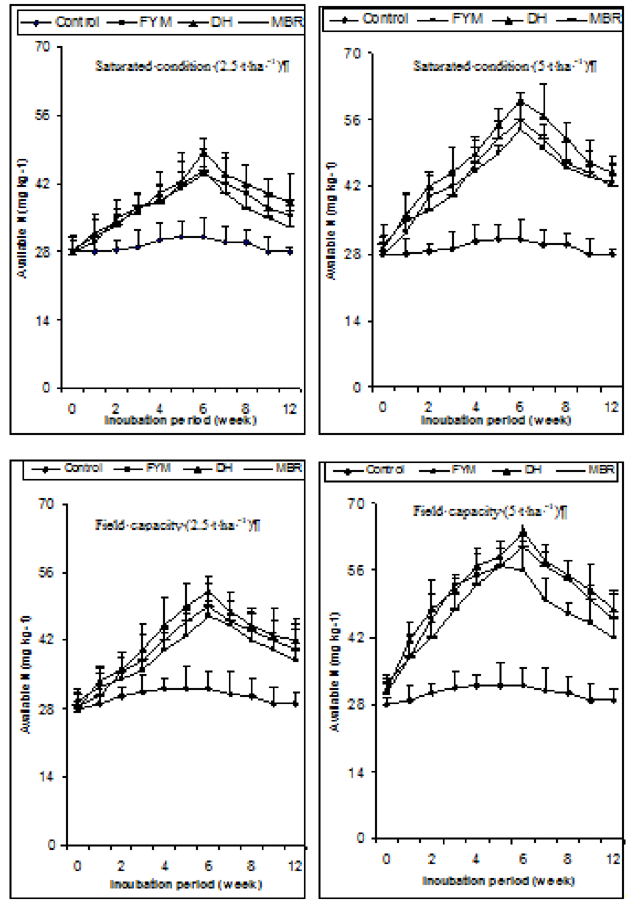

Fig. 2: Available N release pattern at OFRD farm soil amended with manure, crop

of added N) with mungbean residue and 29 mg kg^{-1} (66% of added N) due to *Sesbania* incorporation, under saturated condition (Table 4). At field capacity, the net N-mineralization was 25 mg kg^{-1} (69% of added N) with farmyard manure, 29 mg kg^{-1} (75% of added N) with mungbean residue and 32 mg kg^{-1} (73% of added N) with *Sesbania* incorporation at the rate of 5 t ha^{-1}. Similar trend of net N-mineralization was found when the soils were amended with 2.5 t ha^{-1}, but the magnitudes were different. Higher N mineralization was observed in both the soils and moisture condition where, the soils were amended with higher rates of manure and crop residue (5 t ha^{-1}), but the per cent N mineralization was higher with lower rate of organic matter application.

Nitrogen mineralization potential and rate constant for different manures and crop residues were calculated for both soils and moisture conditions (Table 5). The mineralization potentials for N from manure and crop residues were higher with the higher rate (5 t ha^{-1}) compared to the values obtained with lower rate (2.5 t ha^{-1}) of application. In both the soils, mineralization potential for manure and crop residues was higher under saturated condition compared to field capacity. At field capacity among the organic materials, mungbean residues showed the higher mineralization potential in both the soil moistures and rates of organic materials application except *Sesbania* 5 t ha^{-1} for BAU farm soil. On the other hand, the OFRD farm soil the highest nitrogen mineralization potential was found with *Sesbania* for both the rates and soil moistures. At BAU farm soil under field capacity, the higher value of rate constant (0.290–0.449) was recorded due to lower rate (2.5 t ha^{-1}) of manure application and the highest value (0.449) was obtained with *Sesbania* treated soil. At saturated condition, the higher value (0.131–0.252) was obtained with higher rate (5 t ha^{-1}) of manure application. In case of OFRD farm soils, the higher value was noted with higher rate of manure and crop residues for both the soil moisture regimes. The highest value was recorded with farmyard manure treated soils (0.456). It revealed that the calculated and predicted values of net N mineralization for different manure and crop residues were highly correlated with each other (Table 6). The R^2 values laid 0.8671 to 0.9601, which indicate highly significant with calculated and predicted values.

Table 5: Nitrogen mineralization potential (No) (mg kg^{-1}) and rate constant (k) for soil amended with different sources of organic manure and crop residues during 5 - 7 weeks of incubation

Organic manure/crop residue	BAU farm soil, Mymensingh							
	Saturated condition				Field capacity			
	2.5 t ha^{-1}		5 t ha^{-1}		2.5 t ha^{-1}		5 t ha^{-1}	
	No	k	No	k	No	k	No	K
Farmyard manure	21.14	0.220	40.26	0.140	16.40	0.326	27.84	0.303
Dhaincha (*Sesbania*)	26.47	0.198	40.14	0.252	19.37	0.449	39.13	0.243
Mungbean residue	27.96	0.116	47.68	0.131	19.87	0.290	33.79	0.228
	OFRD farm soil, Rangpur							
Farmyard manure	21.01	0.143	37.62	0.143	18.89	0.250	27.03	0.456
Dhaincha (*Sesbania*)	35.50	0.068	48.42	0.140	24.50	0.200	34.31	0.346
Mungbean residue	33.44	0.081	42.50	0.155	22.13	0.215	33.70	0.397

Table 6: Correlation between the calculated and predicted available N (mg kg^{-1}) at BAU and OFRD farm soils under different moisture regimes

Locations and Soils	Moisture regime	Rate of organic materials	Regression equation	Values of coefficient correlation (r)
BAU farm soil	Saturated condition	2.5 t ha^{-1}	y = 1.0037x - 0.8581	r = 0.9312
		5 t ha^{-1}	y = 0.9704x + 0.468	r = 0.9798
	Field capacity	2.5 t ha^{-1}	y = 1.0182x - 0.3607	r = 0.9612
		5 t ha^{-1}	y = 0.9704x + 0.468	r = 0.9798
OFRD farm soil	Saturated condition	2.5 t ha^{-1}	y = 0.9842x + 0.1738	r = 0.9502
		5 t ha^{-1}	y = 0.9428x + 0.3988	r = 0.9593
	Field capacity	2.5 t ha^{-1}	y = 1.0486x – 1.5362	r = 0.9368
		5 t ha^{-1}	y = 0.8604x + 1.9143	r = 0.9332

Discussion

Soil organic matter is a key factor in maintaining long-term soil fertility since it is the reservoir of metabolic energy, which drives soil biological processes involved in nutrient availability. Soil organic matter undergoes mineralization and releases all the mineral nutrients into the soil. After the application of organic manure into the soil, readily decomposable nitrogenous substances mineralized first. Amelioration of salt-affected soils necessitates the replacement of Na^+ by Ca^{2+} cations, which can be done chemically or by using organic wastes, which was found to be a strategy, especially in arid regions (Garcia, 2000). It was found from a study using different manures for N mineralization that monitoring of mineral N release during decomposition of manures is a useful tool for fertilization programs that include incorporation of organic sources of N (Yousif and Abdalla, 2009).

A portion of mineralized N is immobilized by microorganisms and the rest of N is released in the soil as available N (Mary *et al.*, 1996). The amount of this available N will be higher if the soil amended with organic manure of lower C:N ratios or higher N content. It is indicated that as the N mineralization proceeds, the mineralizable N resistance becomes higher and then the mineralization rates become smaller (Sihag and Singh, 1999). It was reported that the reason for decrease in available N can be attributed to the utilization of N by increasing microbial population and simultaneous loss through denitrification. At the later stages, the rate of denitrification loss of N exceeds the rate of mineralization of organic N as a result the values were lower (Zaman, 2002). In both BAU and OFRD farm soils, the mineralization of organic nitrogen was slightly higher at field capacity compared to that at saturated condition. It was reported that when green manure N was added, the maximum N mineralization occured at 50% water holding capacity (WHC) followed by 75% and 25% WHC (Sihag and Singh, 1999).

Nitrogen mineralization pattern from manure and crop residues in both the soils was initially very low followed by a faster rate up to 5–7 weeks of incubation and then declined with time. The NH_3 volatilization losses after 1 week of soil submergence were negligible for *Sesbania* amended and un-amended soils, this was probably, because simultaneous nitrification-denitrification reactions (Sihag and Singh, 1997). The fluctuations of NH_4-N release during the first two weeks of incubation suggest a loss of NH_4-N from the manure by NH_3 volatilization. The decline in soil NH_4-N between weeks zero to week two can be explained by an event of rapid nitrification combined with denitrification. The fact that the soil NO_3-N did not increase between one and two of the incubation interval suggests that the NO_3-N was taken up by the denitrifiers as soon as it was produced, preventing an increase in the standing NO_3-N pool, because of restricted aeration, which encourages denitrification (Calderon *et al*., 2004). This close coupling between nitrification and denitrification has been observed by others and resulted in a high proportion of the mineralized N to be loss as N gas (Meyer *et al.*, 2002). For both the farm soils amended with manure and crop residue application, the net N-mineralization under saturated condition followed the order: *Sesbania* >mungbean residue> farmyard manure, but the magnitude of net N-mineralization was different. The differences in N mineralization among the organic materials studied were larger as expected from their initial

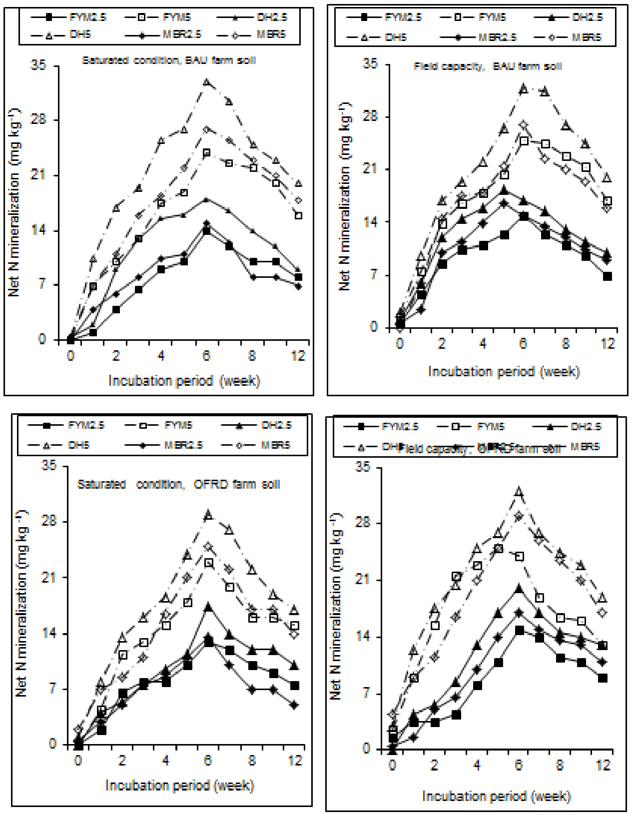

Fig. 3: Net N mineralization pattern at BAU and OFRD farm soils amended with manure, crop residues at two different rates of manure and crop residues application under saturated and field capacity condition

FYM = Farmyard manure, DH = Dhaincha, MBR = Mungbean residue

characterization. Other workers have found that laboratory incubations of manured soil lasting for weeks may result in negative mineralization values (Eneji *et al.*, 2002), while longer incubations resulted in positive values. However, waiting for more than 10 weeks for positive N mineralization would miss the period of high N demand of most crops in the soil are planted soon after manuring the field (Calderon *et al.*, 2004).

On the other hand, among the organic materials the mineralization potential was higher for mungbean residue followed by *Sesbania* and farmyard manure at both the rates of manure and crop residue application. A relationship between the amounts of cellulose or cellulose plus hemicellulose and the amounts of mineralized N of the added organic materials were negative. Mineralization process normally depends on these variations likely differences in soils, organic materials, C/N ratios, application rates, and environmental conditions. Nitrogen mineralization proceeded gradually with a number of microorganisms, which facilitate the process (Haney *et al.*, 2004). The N mineralization-immobilization turnover was influenced by the type of soil and residue used (De Neve *et al.*, 2004). This could be due to the toxicity effect of their polyphenolic compounds on the soil microbial biomass involved in the process of N mineralization, because of their capacity to bind proteins through their strong affinity for amide groups.

In conclusion, Farmyard manure can be used as good source of soil organic matter. Growing a legume in the cropping sequence has special significance in the maintenance of soil fertility and crop productivity. The present study revealed that the release of N from organic matter amended soils increased progressively and attained its peak at 5–7 weeks of incubation at field capacity, while at saturated condition, the highest values were found at 4–6 weeks. It was also observed that an amount of 64–91% N can be released during the study period depending on the types and rates of application of organic manure as well as soil moisture level. So, it is the demand of time to find out the environment friendly organic materials to develop suitable combination with inorganic fertilizers for maintaining better soil health, crop yield and improving nutrient use efficiency.

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