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SOIL SCIENCE

Studies on *In situ* Net N Mineralization in Soils from Mathura Tea Garden and Cultivated Land of North Bengal

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Abstract

Organic matter is one of the sources of nitrogen in the soil. Nitrogen mineralization depends on application method, kind of organic matter, microbial activity, aeration and moisture. Soil samples were taken from Mathura tea garden and Uttar Banga Krishi Viswavidyalaya cultivated field, West Bengal. Nitrogen mineralization was studied on tea soil and cultivated soil. Seven organic matters were collected for this study. Vermicompost (VC), farm yard manure (FYM), poultry manure (PM) were decomposed, whereas, raw cow dung (RCD), fish meal (FM), tannery waste (TW) and mustard cake (MC) were undecomposed. The mean maximum and minimum soil temperature for the entire *in situ* incubation period were respectively 26.33°C and 16.03°C. Net mineralization data (mg N/kg soil) showed that over the period of 84 days it varied from 26.43 to 62.19 for VC, , 7.77 to 31.09 for FYM, 36.86 to 72.62 for PM, 32.65 to 76.19 for RCD, 59.08 to 106.51 for FM, 76.96 to 119.72 for TW and 29.54 to 108.06 for MC. The average of the weekly mineralized nitrogen from organic matter was in the decreasing order of TW >FM>MC >PM>RCD>VC>FYM.

Highlight

- This study evaluated Net N mineralization from organic matter.
- *In situ* N mineralization data exhibited that high nitrogen containing organics had higher net mineralized nitrogen as compared to other in both tea garden and cultivated field soil.

Keywords: Organic matter, soil, N mineralization, FYM, soil temperature

Nitrogen (N_2) is generally the most common growth-limiting nutrient in agricultural production systems. N_2 availability is mainly determined by N_2 mineralization through transforming organic N_2 to inorganic form (Zhou *et al.*, 2009). The N_2 taken up by crops is derived from a number of sources, particularly from fertilizer, biological N fixation and mineralization of N_2 from soil organic matter, crop residues and manures (Keeney, 1982). N_2 mineralization is usually considered as a key process in these ecosystems (Ross et al. 2004). The contribution of mineralization to crop N_2 supply may range from <20 to >200 kg N ha^{-1} (Goh 1983; Cabrera *et al.*, 1994) depending on the quantity of mineralizable organic N_2 in the soil and environmental conditions (soil temperature and moisture) that control the rate of mineralization. Mineralization in the soil and significant N_2 content of its mineral, the available form of N_2 can be released, satisfying crop requirements for N_2 (Amlinger *et al*., 2003; Bavec *et al*., 2006).

The plant takes up nitrogen as NO_3=-N or NH_4^+–N. Soil nitrogen supply through organic carbon from plant material and animal residues are transformed by microbial activity to NH_4^+ and further on to NO_3= by nitrification during mineralization. N_2 mineralization is a relatively slow microbial process which is affected by factors such as aeration and moisture. N_2 as NO_3= is soluble and mobile and susceptible to transport to groundwater, which has become increasingly degraded by NO_3= (Strebel *et al*., 1989; Spalding and Exner, 1993). NO_3= is generally the dominant form of NO_3= where total NO_3= levels are elevated. NO_3= and other forms of NO_3= in water can be from natural sources, but when NO_3= concentrations are elevated; the sources are typically associated with human activities (Dubrovski *et al*., 2010).

Organic manures also vary in the quantity of organic NO_3= that they contain at the time of application in the field. Mineralization during the growing season will provide a supply of NO_3= that can meet a large part of the crops' NO_3= demand, but the amount of NO_3= release has proved difficult to predict. There is an urgent need to improve our understanding of the processes involved in the transformation of NO_3= following application of manures and organic substrates to soils in order to achieve better synchrony between plant uptake and nutrient release, while avoiding excess nutrient loss from farming systems.

Materials and Methods

Soils under study and their collection

Composite surface soil samples from 0-15 cm depth from two locations of Mathura tea garden and Uttar Banga Krishi Viswavidyalaya cultivated field, West Bengal were collected. Soils were air dried in shade and ground to pass through a 2 mm sieve and retained for analysis. The physico-chemical properties are presented in Table 1.

Organic matter used in the experiments

Seven organic matters were collected for this study. Vermicompost (VC), farm yard manure (FYM), poultry manure (PM) were decomposed, whereas, raw Cow Dung (RCD), fish meal (FM), tannery waste (TW) and mustard cake (MC) were undecomposed. Vermicompost was collected from market, air-dried and sieved through 2 mm sieve. It was kept in refrigerator for further use. Raw cow dung (7 days old) was collected from a dairy farm and kept in the refrigerator. FYM was collected from cattle farm; air-dried and kept in refrigerator. It was sieved through 2 mm sieve.

Table 1: Physico-Chemical properties of soils under study*

Properties	Soil	
	Mathura tea garden	UBKV cultivated field
pH	4.38±0.30	5.34±0.67
Organic Carbon (%)	1.16±0.10	1.02±0.08
CEC [Cmol (P^+)/kg]	4.45±.040	5.63±0.06
$NH4^+$-N (mg/kg)	52.59±1.01	42.30±0.97
$NO_3^=$-N (mg/kg)	69.74±4.75	52.59±1.45
Available P (mg/kg)	8.62±0.54	7.30±0.12
Available K (kg/ha)	88.41±3.41	76.90±7.45
Total N (%)	0.11±0.04	0.08±0.00
Total P (%)	0.02±0.01	0.03±0.01
Bulk Density ($gmcc^{-1}$)	1.06±0.03	0.89±0.04
Particle Density ($gmcc^{-1}$)	2.25±0.15	2.12±0.05
Maximum Water Holding Capacity (%)	69.20±4.85	83.34±0.95
Sand (%)	64.30±0.26	53.50±0.31
Silt (%)	22.60±1.45	31.10±0.09
Clay (%)	13.10±0.88	15.40±0.98

**Average of three replicates ± RSD*

Poultry manure was collected from a local poultry farm. It is a common practice in this locality to use saw dust at the time of litter collection of poultry manure, however, the manure was well decomposed. It was air dried and sieved through 2 mm sieve. Fish meal (Dry fish-without salt and preservatives) was collected from local market and it was then oven dried at 60˚C for 12 hrs, pulverized in mixer-grinder and sieved through 0.8 mm sieve. Tannery waste is a waste produced in leather industry and it was collected from leather industry, Kolkata, oven dried at 60˚C for 12 hrs. It was pulverized in mixer-grinder and sieved through 0.8 mm sieve. Mustard cake was collected from local market and oven dried at 60˚C for 12 hrs. It was also pulverized in mixer-grinder and sieved through 0.8 mm sieve.

Physico-Chemical properties of soil

Mechanical analysis was determined following the method described in Barua and Barthakur, 1997. Maximum water holding capacity was determined by Keen and Rockzowski's method (Barua and Barthakur, 1997). pH of the soils was determined using soil suspension in water (1:2.5) (Jackson, 1973). Organic carbon of soil samples was estimated by Walkley and Black method (Nelson and Sommers, 1982). Electrical Conductivity of the suspension (soil: water:: 1:2) was determined by Jackson (1973). Available N was determined by the method of Kenny and Bremner (1966) as described by Page *et al.* (1982). Available P was determined by Bray and Kurtz (1945). Available K was determined by Barua and Barthakur (1997). Total N was determined by modified Kjeldhal digestion method. Total P was determined by Jackson (1973) and Cation Exchange Capacity was determined by Jackson (1973).

In situ N-mineralization study

In the present investigation seven different types of organic matters viz. vermincompost (VC), raw cow dung (RCD), farm yard manure (FYM), poultry manure (PM), fish meal (FM), tannery waste (TW) and mustard cake (MC) were used. Among these organics, VC, FYM and PM were decomposed, whereas RCD, FM, TW and MC were undecomposed. Some of the essential quality parameters were analyzed. Nitrogen content of various organic matters, used under study, varied from 0.83% to 9.29% (Table 2). Net nitrogen mineralization from organic matter was done in tea and field soils with the help of buried bag technique. The bags were buried at Pundibari and the experiment was continued for 84 days. For *in situ* nitrogen mineralization study, air dried soils are amended with organic matter @ 150 mg organic nitrogen kg^{-1} soil, deionized water was added to soil (mixed with organic matter) to raise the moisture content up to 45% of water holding capacity. 100 gm of amended soil was packed in polyethylene bag (20 μm thickness), the opening of the bag was folded several times and stapled to seal the bag with the help of buried bag technique (Hanselman *et al*., 2004).

In situ incubation methods may help provide site-specific estimates of N mineralization from land-applied wastes. However, there are concerned about the reliability of the data generated by the various methods due to containment artifacts. A sandy soil with either poultry manure, bio-solids, or yard-waste compost was amended and incubated the mixtures using four *in situ* methods (buried bags, covered cylinders, standard resin traps, and "new" soil-resin traps) and a conventional laboratory technique in plastic bags (Hanselman, *et al*., 2004). Three replications were taken for all the treatments including control (soil only) and total 36 bags buried for each treatment. All the bags containing amended soils were buried within 15 cm of soil. Three replicates were destructively sampled in each of the 12 weeks. Mineral N_2 in the soil was extracted by 2 M KCl (1:4 soil to solution ratio, weight basis) and determined by steam distillation (Keeney and Nelson 1982). Cumulative net nitrogen mineralized

Table 2: Quality of various organic matter of low and high total nitrogen content*

Organic Matter	Moisture (%)	TOC (%)	$NH4^+$-N (mg/kg)	NO_3=-N (mg/kg)	TMN (mg/kg)	TN (mg/kg)	TON (mg/kg)	C: N	PH	TN (%)	Total-P (%)	Total-K (%)	WSC (mg/kg)	HWSC (mg/kg)	Ash (%)
VC	177.5	18.50	955	1313	2268	8304	6036	22.0	5.73	0.83	0.31	0.21	767	3105	66.7
RCD	330.5	42.65	2224	1481	3705	11000	7295	38.8	8.11	1.10	0.11	0.11	1380	3987	23.1
FYM	66.0	27.24	500	571	1071	9493	8422	28.6	7.04	0.95	0.50	0.15	1073	6900	51.0
PM	114.5	29.13	861	1231	2092	22879	20787	12.7	6.10	2.29	1.08	0.20	728	2990	47.6
FM	20.39	36.92	5400	688	4023	88506	84483	4.2	5.82	8.85	1.74	0.56	5254	5673	33.1
TW	18.8	36.02	5480	1015	6495	92984	86489	3.8	6.04	9.29	0.17	0.10	7245	4830	35.0
MC	16.79	44.84	904	502	573	69497	68924	7.70	4.97	6.95	1.03	0.61	7398	5903	19.0

**Average of three replication and results are expressed on dry weight basis*

VC = Vermicompost, RCD = Raw Cow Dung, FYM = Farm Yard Manure, PM = Poultry Manure, FM =Fish Meal, TW = Tannery Waste and MC = Mustard Cake

TOC = Total Organic Carbon, TMN = Total Mineralizable Nitrogen, TN= Total Nitrogen, TON = Total Organic Nitrogen, WSC = Water Soluble Carbon and HWSC = Hot Water Soluble Carbon of the organic amendments at each extraction time was calculated from the equation (Hanselman, *et al*., 2004)

Nm = Ni (soil + organics) – Ni (initially in organics) – Ni (incubated control soil)

Where, Nm is mineralized nitrogen; and Ni is inorganic nitrogen at each extraction time.

Maximum (at 1-30 p.m.) and minimum (at 5-30 a.m.) soil temperature at 15 cm depth was recorded at two days interval (three reading per week) in a week during the entire field incubation period.

Table 3: Maximum-Minimum soil temperature (°C) at 15 cm depth*

Week	Maximum(°C)	Minimum(°C)
1	25.20±0.20	16.85±0.14
2	26.85±0.57	16.85±1.83
3	26.30±0.30	16.30±0.35
4	28.30±0.52	16.85±0.70
5	27.00±1.73	16.30±0.90
6	28.00±1.00	16.67±0.52
7	22.00±1.00	15.20±0.35
8	25.40±0.40	13.50±0.87
9	25.00±1.73	15.70±0.10
10	26.85±0.60	15.55±0.50
11	28.00±1.00	16.85±0.10
12	27.00±0.00	15.74±1.08
Mean	26.33±0.30	16.03±1.73

**Average of three replicates ± RSD*

Statistical Analysis

The experiment suits with CRD with seven types of organic matter each in three replications. Data from laboratory studies were analyzed using the MSTAT package.

Results and Discussion

In situ nitrogen mineralization study

Net nitrogen mineralization from organic matter was done in tea and cultivated field soils with the help of buried bag technique. The bags were buried at Pundibari and the experiment was continued for 84 days. Mean soil temperature for each week was presented in table 3. The mean maximum and minimum soil temperature for the entire *in situ* incubation period were 26.33°C and 16.03°C. Net mineralization data (mg N/kg soil) showed that over the period of 84 days it varied from 26.43 to 62.19 for VC, 7.77 to 31.09 for FYM, 36.86 to 72.62 for PM, 32.65 to 76.19 for RCD, 59.08 to 106.51 for FM, 76.96 to 119.72 for TW and 29.54 to 108.06 for MC (Fig. 1). The average of the weekly mineralized nitrogen from organic matter were in the decreasing order of TW >FM>MC >PM>RCD>VC>FYM (Fig. 2). Almost similar trend was observed in case of cultivated soil except poultry manure and the order is TW (78.52%), FM (71.27%), MC (53.32%), RCD (37.32%), VC (16.39%), PM (16.20%) and FYM (15.87%)

Table 4: Net nitrogen mineralization from organic matter for 84 days in Mathura tea soil*

	Organic Matter						
Incubation (Days)	**VC**	**RCD**	**FYM**	**PM**	**FM**	**TW**	**MC**
7	29.54	43.53	31.09	43.08	77.74	79.30	29.54
14	41.20	52.09	27.21	50.85	84.74	93.29	42.37
21	48.20	59.08	17.10	66.40	101.07	119.72	71.52
28	52.09	64.52	16.32	70.29	106.51	117.39	89.79
35	62.19	76.19	12.43	63.29	96.40	115.84	108.06
42	60.64	63.75	10.88	49.30	87.07	90.18	107.29
49	40.42	65.30	9.32	64.85	88.63	80.85	94.85
56	32.65	63.75	7.77	72.62	96.40	90.18	100.29
63	29.54	46.64	9.32	57.07	77.74	85.52	96.40
70	26.43	38.87	13.99	50.85	73.08	87.07	88.63
77	31.09	38.87	15.54	36.86	62.19	99.45	86.29
84	32.65	32.65	13.99	36.86	59.08	76.96	79.30
Mean	40.55	53.77	15.41	55.19	84.22	94.65	82.86

**Average of three replicates*

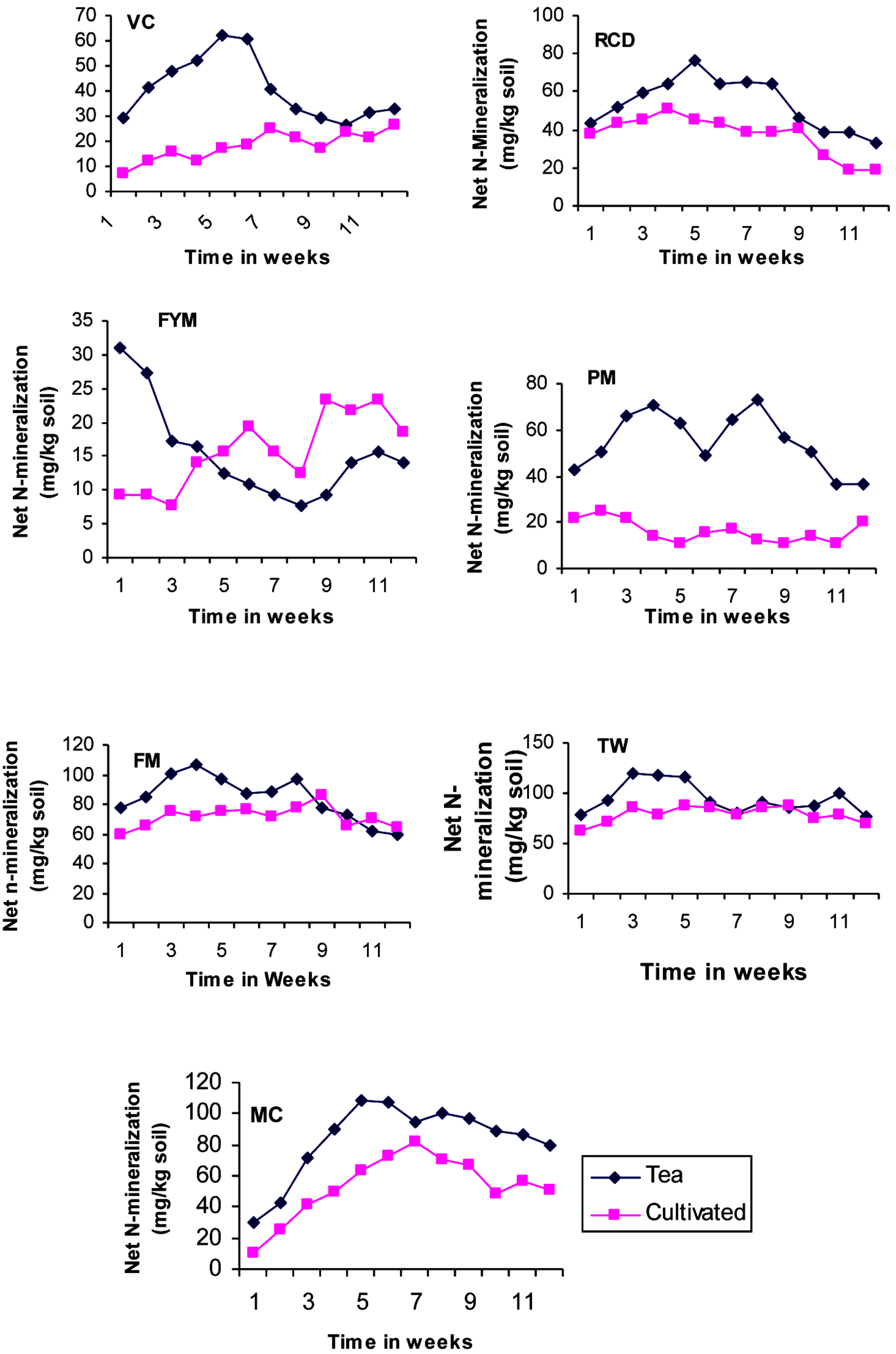

Fig. 1: Net N2-mineralization from organic matter in Mathura tea garden and cultivated field soil

Table 5: Net nitrogen mineralization from organic matter for 84 days in cultivated field soil*

	Organic matter						
Incubation (Days)	**VC**	**RCD**	**FYM**	**PM**	**FM**	**TW**	**MC**
7	6.99	37.31	9.32	21.76	59.08	62.19	10.88
14	12.43	43.53	9.32	24.87	65.30	71.52	24.87
21	15.543	45.09	7.77	21.76	74.63	85.52	41.98
28	12.43	51.31	13.99	13.99	71.52	77.74	49.75
35	17.10	45.09	15.54	10.88	74.63	87.07	63.75
42	18.65	43.53	19.43	15.54	76.19	85.52	73.08
49	24.87	38.87	15.54	17.10	71.52	77.74	82.41
56	21.76	38.87	12.43	12.43	77.74	85.52	70.74
63	17.10	40.42	23.32	10.88	85.52	87.07	66.86
70	23.32	26.43	21.76	13.99	65.30	74.63	48.20
77	21.76	18.65	23.32	10.88	69.97	77.74	55.97
84	26.43	18.65	18.65	20.21	63.75	69.97	51.31
Mean	16.39	37.32	15.87	16.20	71.27	78.52	53.32

**Average of three replicates*

(Fig. 1). The mineralization pattern of organic matter in both the soils, presented in (Fig. 1), exhibited that the mineralized nitrogen of VC, RCD, PM, TW and MC were higher in tea soil for entire incubation period of 84 days. In case of FYM, up to 28 days the mineralized nitrogen was higher in tea soil and then it showed lower mineralized N_2 than cultivated soil.

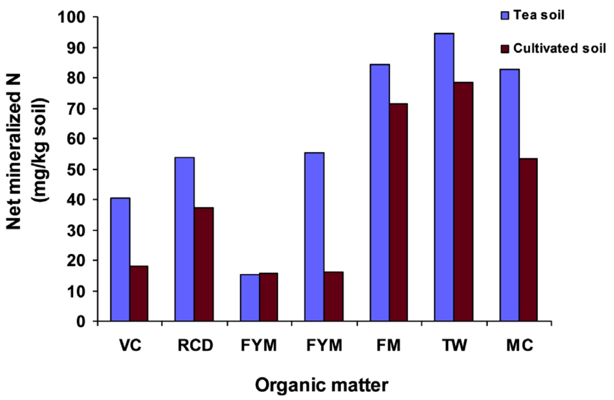

Fig. 2: Weekly average of net N2-mineralization of Mathura tea garden and cultivated field soil

The difference in net N_2-mineralization is attributed to the differences in biological properties and soil organic matter quality of these two soils. As the net nitrogen mineralization organic matter is calculated by subtracting the mineral nitrogen of incubated control soil from the incubated manured soil, it depends on two variables-(i) Net N_2-mineralization of control soil and (ii) net N_2 mineralization of manured soil which ultimately governed by the quality of soil organic matter and added organic matters, respectively and finally the composition and activity of microorganisms in both the treatments.

With the help of buried bag technique Hanselman, *et al*. (2004) observed 42, 60, 63, 67 and 32% organic nitrogen mineralization from poultry manure respectively at 3, 45, 90, 135 and 180 days of incubation and at these days the mineralization from bio-solid was 19, 47, 45, -11 and -11% of organic matters.

Conclusion

In situ nitrogen mineralization data exhibited that high nitrogen containing organics had higher net mineralized nitrogen as compared to other in both tea and cultivated soil. Tea soil supported better net mineralization as compared to cultivated soil except FYM.

In situ nitrogen mineralization data exhibited that high nitrogen containing organics had higher net mineralized nitrogen as compared to other in both tea and cultivated field soil. Tea soil supported better net mineralization as compared to cultivated soil except FYM.

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