International Journal of Bioresource Science
Citation: IJBS: 4(1): 47-56, June 2017
DOI: 10.5958/2454-9541.2017.00009.3

Evaluation of Chemical and Biological Indices for Carbon and Nitrogen Mineralization of Various Organic Matters Used in Tea Garden

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ABSTRACT

The objective of this study was to evaluate the performance of chemical and biological indices to predict carbon and net nitrogen mineralization from a range of organic amendments that differed in their total carbon and nitrogen and the carbon quality. Three decomposed materials i.e. vermi compost (VC), farm yard manure (FYM), poultry manure (PM) and four un-decomposed materials i.e. raw cow dung (RCD), fish meal (FM), tannery waste (TW) and mustard cake (MC) were used for the experiment. Carbon mineralization was determined using alkali traps. Aerobic nitrogen mineralization was estimated using incubation and leaching method, whereas, anaerobic N-mineralization was done under waterlogged condition at 40°C. It was observed that water soluble organic carbon (WSOC) had significant correlation with C-mineralization (r=0.885**) and net aerobic N-mineralization (r=0.805*). Linear regression analysis also exhibited that WSOC had a very high linear relation with C-mineralization (r^2=0.7835) and net N-mineralization (r^2=0.649). Biological parameter i.e. 7 days anaerobic N-mineralization (ANI7) at high temperature exhibited significant correlation with C-mineralization (r=0.960**) and net aerobic nitrogen mineralization (r=0.855*). Net N-mineralization (aerobic) when regressed against anaerobic nitrogen index i.e. ANI-7, ANI-14 and ANI-21, R^2 value of 0.733, 0.945 and 0.960 were found, respectively, indicating that anaerobic nitrogen mineralization index can be a useful tool for predicting nitrogen mineralizing capacity of various organic matters.

Keywords: Organic matter, N-mineralization, C-mineralization, tea soil

Manure and other organic matters contain substantial amounts of plant nutrients and organic carbon that can be used for crop production and soil improvement. The decomposition of organic matter plays a central role in supplying plant nutrients, both in managed and natural ecosystems. The supply of N from manures and other organic substrates makes an important contribution to the N demand of growing plants. In low input and organic systems such substrates are crucial in supplying plant nutrients in the absence of inorganic fertilizer supplies (Stockdale and Rees, 1995), and even in conventional farming systems there is substantial release of N from manures, offsetting the need to provide mineral fertilizers (Goulding *et al.,* 2001).

Traditionally tea growers of Darjeeling Hills apply less quantity of chemical fertilizers as compared to other area and replace chemical fertilizer to some extent by the use of FYM, compost and poultry manure. Some other types of concentrated organics like fish meal, tannery waste, mustard cakes based products are also marketed in this region. Organic amendments also vary greatly in their composition and degree of stabilization and thus their capacity to release nutrients also vary to a greater extent. Decomposition rate of various organic matters in soil depends on their intrinsic qualities, environmental condition specially temperature and moisture as well as size, diversity and activity of soil microorganisms.

Accurate prediction of the amount of inorganic N released from organic matter is essential for the development of farming practices that maximize N use efficiency and minimize adverse impacts on nitrogen on the environments, unfortunately, the release of nutrients from added organic substrates has proved very difficult to predict. Previous studies have attempted to predict the nutrient value of manures by using their mineral N concentrations at the time of application. This is a valuable approach and can help farmers to prepare simple nutrient budgets (Chambers *et al.,* 1999). However, such approaches do not take account of the processes of mineralization and immobilization that occur after manure application to the field, and ignore any potential changes in the rates of mineralization of background organic matter. Manures vary widely in the amount of mineral N that they contain. Composted materials will generally contain less mineral N than fresh manures, particularly when they are composted aerobically (Kirchmann, 1991). Organic manures also vary in the quantity of organic N that they contain at the time of application in the field. Mineralization during the growing season will provide a supply of N that can meet a large part of the plant's N demand, but the amount of N release has proved difficult to predict (Stockdale *et al.,* 2000). There is an urgent need to improve our understanding of the processes involved in the transformation of N 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.

Inorganic nitrogen can be easily extracted and measured, but mineralizable nitrogen is much more difficult to measure. Traditional methods of determining mineralizable nitrogen in soil and organic materials can be divided into biological and chemical methods. Biological methods measure mineralizable nitrogen by incubating a sample and measuring the inorganic nitrogen released during a long period of time (Castellanos and Pratt, 1981; Chae and Tabatabai, 1986; Bitzer and Sims, 1988). In contrast, chemical methods attempt to extract a chemical fraction that is related to mineralizable nitrogen (Castellanos and Pratt, 1981; Douglas and Mgdoff, 1991; Serna and Pomares, 1991). While biological methods are usually considered more accurate than chemical methods, they are also more laborious and time consuming.

Thus the objective of this study was to evaluate the suitability of various quality parameters of organic matters (chemical methods) and short term anaerobic nitrogen mineralization at high temperature (biological method) as tools to predict the organic carbon and nitrogen mineralization from composted and fresh organic matters.

MATERIALS AND METHODS

Chemicals and reagents

All the chemicals and reagents were AR and GPR quality and were procured from Hi Media, Mumbai, India and Merck, Mumbai, India.

Organic matter used in the experiments

Seven organic matters were collected for this study. Vermi compost (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 un-decomposed. Vermi compost was collected from market, air-dried and sieved through 2mm 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 2mm sieve. 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 2mm sieve. Fish meal: Dry fish (with out salt and preservatives) was collected from local market and it was then oven dried at 60^0C for 12hrs, pulverized in grinder and sieved through 0.8mm sieve. Tannery waste: It is a waste produced in leather industry and it was collected from leather industry, Kolkata, oven dried at 60^0C for 12hrs. It was pulverized in grinder and sieved through 0.8mm sieve. Mustard cake was collected from local market and oven dried at 60^0C for 12hrs. It was also pulverized in mixi grinder and sieved through 0.8mm sieve.

Soil

The 0 to 15 cm layer soil (64.3% sand, 22.6% silt, 13.1% clay; pH [1:2.5]=4.68; org. Carbon=1.16%; total N=0.11%) was collected from tea garden for this study. Soil was air dried in shade and ground to pass through a 2 mm sieve and retained for analysis. A portion of the soil was oven dried at 105º C for eight hours for calculation of moisture percentage. All results are reported on oven dry basis.

Analysis of quality parameters of Organic maters:

Ash percentage of all the organic matters was determined by dry combustion at 600^0C for 5-6 hrs. Total organic carbon (TOC) and total N were determined by CHNS analyzer (Model Vario EL III Element analyzer, Germany). Mineral Nitrogen i.e. ammonium-N, nitrate-N were determined by N-autoanalyzer (FIAstar™ 5000 Analyzer, FOSS Tecator, Sweden). Total organic nitrogen was calculated by subtracting the total mineral nitrogen from total nitrogen of each sample. Total-P, total-K were analyzed by standard methods as described by Jackson (1967).

Water soluble carbon (WSC)

Water soluble carbon was extracted with distilled water using organics and solution ratio of 1:30. Organic matter (equivalent 1g oven dry basis) was weighed into 50ml polypropylene centrifuge tubes. Carbon were extracted with 30ml of distilled water for 30 minutes at 25°C, centrifuged for 15 minutes for 8000 rpm and the supernatant was filtered through 0.45 μm membrane filter into separate vials for carbon analysis. Carbon was analyzed by the method of Nelson and Sommers (1982).

Hot water soluble carbon (HWSC)

After the extraction of WSC, a further 30ml of distilled water was added to the sediments. These tubes were shaken on a vortex for 10 seconds to suspend the organics in the water. HWSC was extracted at 80°C for 16 hours (Haynes and Francis, 1993). After the extraction, tubes were shaken on vortex, centrifuged for 15 minutes at 8000 rpm and supernatant was filtered through 0.45 μm membrane filter into separate vials for carbon analysis. Carbon was analyzed by the method of Nelson and Sommers (1982).

Carbon mineralization from organic matter

100 gm soil (oven dry basis) was weighted, amended with various organic matter @ 2.5 g C kg^{-1} soil, water was added to raise the moisture to 45% of water holding capacity and taken into 500ml conical flasks. 10 ml of 1.0 N NaOH was taken in test tube. The tubes were hanged with the help of thread inside the conical flask without touching the soil. The flasks were made airtight by rubber stopper and incubated at 25^0C appropriately. A blank was maintained only with NaOH. The flask was opened periodically and removed the NaOH from beaker for CO_2 determination. The flask was allowed to remain open when the titration procedure was done. This was done to replenish O_2 in the jar for the next incubation period. 25ml of CO_2 free water was added an access of 3N $BaCl_2$, and 3 or 4 drops of phenolphthalein indicator and titrated with 0.5N H_2SO_4. NaOH from the blank was titrated in the same manner.

N-mineralization under anaerobic condition

The anaerobic incubation procedure (waterlogged) used in the study was previously described by Waring and Bremner (1964) and modified and developed by Keeney (1982) and is strongly recommended for the assessment of the mineralizable N during an incubation period. The method involves the incubation of a soil sample under waterlogged conditions in an enclosed test tube with as little headspace as possible in the tube. Distilled water of about 12 ml was placed in a 16 ×150 mm screw cap test tube, and then 5 gm of oven dry equivalent soil, amended with organic matter @ 100 mg organic nitrogen kg^{-1} soil, was added to the tube. The test tubes were capped and placed in a constant temperature water bath maintained at 40°±1°C. Three replicates of eight treatments (VC, RCD, FYM, PM, FM, TW, MC and control) were maintained for three sets. At the end of 7, 14 and 21 days, the tubes were removed from the water bath and shaken briefly to mix the content. The soil water mixture of each tube was quantitatively transferred to a 150-ml distillation flask. About 50 ml of 2M KCl was used to extract the mineral nitrogen. The mineral nitrogen was estimated by distillation method.

Net nitrogen mineralization of amended soil was estimated by (i) subtracting the amount of inorganic nitrogen present in initial soil and organic matter from the amount of inorganic nitrogen extracted from soil after incubation. Net nitrogen mineralization of organic amendments was estimated by (ii) subtracting the amount of net mineralized nitrogen of control soil from the first step.

Nitrogen mineralization under aerobic condition (Incubation and leaching method)

Soil was air dried and sieved prior to incubation. 100gm of soil was mixed with sand at soil: sand ratio of 1:2.5. This was mixed with organic matter @ 100mg organic N kg^{-1} soil. The soil-sand mixture (80 gm) for each tube was moistened with a thin spray of water to prevent particle size segregation during transfer to leaching tubes (3 cm diameter and 18.5 cm length). The soil-sand mixture was supported in the tube on a glass wool pad (Stanford and Smith, 1972). A thin glass wool pad was placed on top of the soil to avoid soil dispersion when the leaching solution is poured into the tube. The mineral N initially present is leached from the system using 100 ml of 0.01 M $CaCl_2$ in small increments (10 ml at a time) followed by 20 ml of the N-minus nutrient solution. The excess solution was removed by evacuation (60 cm Hg) and discarded. The tubes were then stoppered at both end and placed in an incubator set at 25°C. Each day the top stopper was removed for 5 min to allowed aeration. The leaching process was prepared every one week for 8 weeks. The leachate was collected, filtered through whatman no.1 filter paper, and a blank was prepared. The leachate was analyzed for (NO_3^- + NH_4^+) - N. When leaching, the soils are initially allowed to drain freely; vacuum is applied only to remove excess solution. Mineral nitrogen present in leachate of each extraction time was considered as net mineralized nitrogen in a week. Net mineralized nitrogen of organic amendment was calculated by subtracting the amount of mineral nitrogen from the amount of inorganic nitrogen of amended soil.

RESULTS AND DISCUSSION

Organic matter Characterization

In the present investigation seven different types of organic matters viz. vermicompost (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, PM were decomposed, whereas RCD, FM, TW and MC were un-decomposed. Nitrogen content of various organic matters, used under study, varied from 0.83% to 9.29% (Table 1). On the basis of nitrogen content organics can be categorized as (a) low nitrogen containing organic matters i.e. vermicompost (0.83%), FYM (0.95%), raw cow dung (1.1%) and poultry manure (2.29%), and (b) high nitrogen containing organics i.e. mustard cake (6.95%), fish meal (8.85%), and tannery Waste (9.29%). Total mineral nitrogen of VC, RCD, FYM and PM varied from 1071 to 3705

Table 1: Quality of various organic matter of low and high total nitrogen content*

Organic Matter	Moisture (%)	TOC (%)	NH_4-N (mg/kg)	NO_3-N (mg/kg)	TMN (mg/kg)	TN (mg/kg)	TON (mg/kg)	C: N	pH	Total-P (%)	Total-K (%)	WSC (mg/kg)	HWSC (mg/kg)	Ash (%)
VC	177.5	18.50	955	1313	2268	8304	6036	22.3	5.73	0.31	0.21	767	3105	66.7
RCD	330.5	42.65	2224	1481	3705	11000	7295	38.8	8.11	0.11	0.11	1380	3987	23.1
FYM	66.0	27.24	500	571	1071	9493	8422	28.7	7.04	0.50	0.15	1073	3900	51.0
PM	114.5	29.13	861	1231	2092	22879	20787	12.7	6.10	1.08	0.20	728	2990	47.6
FM	20.39	36.92	5400	688	4023	88506	84483	4.2	5.82	1.74	0.56	5254	5673	33.1
TW	18.8	36.02	5480	1015	6495	92984	86489	3.9	6.04	0.17	0.10	7245	4830	35.0
MC	16.79	44.84	904	502	573	69497	68924	6.5	4.97	1.03	0.61	7398	5903	19.0

**Average of three replication and results are expressed on dry weight basis, TMN-Total mineral nitrogen; TN-Total nitrogen* mg N per kg of organics, whereas FM, TW and PM had 4023, 6495 and 573 mg mineral N/kg organics, respectively. Total organic nitrogen of various organic matters, which was derived by subtracting the mineral nitrogen from total nitrogen, varied in the decreasing order of TW> FM> MC> PM> FYM> RCD> VC. Total organic nitrogen is very important parameter so far nitrogen mineralization is concerned.

Total organic carbon varied from 18.5% (VC) to 44.84% (MC). The decomposed products, VC, FYM and PM contained 18.5, 27.24 and 29.13% TOC, whereas, the un-decomposed products *i.e*. RCD, FM, TW and MC contained 42.65, 36.92, 36.02 and 44.84% TOC, respectively. Carbon and nitrogen ratios of organic matters varied from 3.9 to 38.8.

Water soluble organic carbon (WSOC) and hot water soluble organic carbon (HWSOC) were also analyzed. There was a distinct trend in WSOC content and it was revealed that high nitrogen containing organics *i.e*. FM, TW and MC contained higher WSOC (5254 to 7398 mg C /kg organics) as compared to VC, RCD, FYM and PM (728 to 1380 mg).

After the extraction of WSOC, hot water soluble organic carbon (HWSOC) were also extracted from the same sample and it was observed that decomposed organic matters *i.e*. VC, FYM and PM had less HWSOC (2990 to 3900 mg C per kg matter), whereas un-decomposed matters contained 4830 (TW) to 5903 mg C (MC). Intrinsic properties of various organics have direct bearing with the decomposition rate and nutrient release pattern from these materials.

Carbon mineralization

A laboratory experiment was conducted to measure the amount of CO_2-C evolved from VC, RCD, FYM, PM, FM, TW and MC amended soils. The cumulative CO_2 evolved (mgCO_2/kg soil) was measured on day 2, 4, 7, 11, 14, 21, 28 and 35 and is presented in table 2. Cumulative CO_2-C produced (mg C/kg soil) was higher in soils treated with FM (2307.0), TW (1890.5) and MC (1518.5) as compared to VC (337.5), RCD (442.5), FYM (379.5) and PM (322.5). Among the fresh or un-decomposed organic matters 92.3% of FM was mineralized with in 35 days followed by TW (72.2%), MC (47.2%), and RCD (17.7%). Among the decomposed or stable organic matters FYM, PM and VC decomposed 15.2, 12.9 and 6.8% of added organic carbon. This variation depends on their degree of stability and it reveals that fish meal was the most unstable and immature compound.

Processes such as composting cause organic compounds to stabilize, reducing the proportion of C and N present in soluble form (Gigliotti *et al.,* 2002). Mature composts that have undergone the complete composting process have a much higher proportion of stable materials than immature or non-composted products (Bernal *et al.,* 1998c). Hence, the application of composted amendments (as opposed to raw manures and non-composted amendments) to soil can reduce the immediate leaching risks when crops are small and N demand is low. In the present study un-decomposed matters have also shown the higher CO_2-C evolution as compared to decomposed products like VC, FYM and PM. Other measures suggested to indicate mature and sta-

Table 2: Cumulative CO_2 evolution (mg CO_2-C per kg soil) of amended soil observed under laboratory incubation study*

Organic matter	Days of incubation							
	2	**4**	**7**	**11**	**14**	**21**	**28**	**35**
VC	64.0	90.5	114.0	141.5	212.5	249.5	308.0	337.5
RCD	67.0	111.5	164.0	187.5	236.5	288.5	374.0	442.5
FYM	76.0	107.5	144.0	169.5	214.5	267.5	340.0	379.5
PM	78.0	102.5	128.0	151.5	183.5	229.5	301.0	322.5
FM	550.5	925.0	1169.5	1432.0	1650.0	1907.0	2146.5	2307.0
TW	139.0	233.5	456.0	771.5	1088.5	1460.5	1724.0	1890.5
MC	260.0	601.5	856.0	1033.5	1205.5	1365.5	1465.0	1518.5
Soil	62.0	82.5	100.0	119.5	141.5	146.5	160.0	168.5

**Average of three replication*

ble composts include cumulative CO_2-C evolution values equivalent to <25% of the total C applied (Bernal *et al.*, 1998b). The CO_2-C evolution values of this study also indicate FM was the most unstable product followed by TW and MC. The ash content generally increases and the CO_2-C evolution rate decreases as the composting process continues and a more stable product is achieved (Wang *et al.*, 2004a). Again these parameters indicated that the VC was the most stable product (66.7% ash) followed by FYM (51.0%) and PM (47.6%).

Anaerobic nitrogen mineralization

Soils amended with PM, FM, TW and MC exhibited higher net nitrogen mineralization capacity for all the three incubation period (7, 14 and 21 days) as compared to soils amended with VC, RCD and FYM (Table 3).

Table 3: Net nitrogen mineralized (mg-N/kg soil) from organics under anaerobic incubation*

Organic matter	Days of incubation		
	7 days	14 days	21 days
VC	6.80	6.86	13.72
RCD	9.147	11.43	12.57
FYM	2.28	6.86	12.57
PM	8.00	20.58	49.16
FM	28.58	34.30	57.16
TW	28.58	43.44	68.60
MC	17.15	28.50	57.16

**Average of three replication*

Soil with TW had the highest mineralization ranging from 34.3 (7 days) to 88.03 (21days) mgN/kg, whereas, VC and FYM amended soils had mineralized nitrogen ranging from 12.57 to 33.15 and 8.00 to 32.01 mg N/kg, respectively. Nitrogen mineralization (net) of organic amendments, when expressed as percentage of organic nitrogen, exhibited that after 21 days VC, RCD and FYM mineralized 13.72%, 12.57% and 12.57% of organic nitrogen added, respectively. PM, FM, TW and MC mineralized 49.16%, 57.16%, 68.60% and 57.16% of organic nitrogen after 21 days of incubation, respectively. Anaerobic nitrogen mineralization of amended soil at higher temperature was conducted to develop rapid mineralization index (anaerobic nitrogen mineralization index, ANI) which can predict the total mineralizable nitrogen.

The anaerobic incubation method was used as one rapid index of potentially mineralizable N of soil. Soil is generally incubated at 40^0C for 7 days to get anaerobic incubation index (ANI), however, in the present study we continued the incubation for 7, 14 and 21 days as because the soil was amended with various kinds (fresh and decomposed) of organic matters. From this experiment it is revealed that fresh or un-decomposed organic matter i.e. FM, TW and MC have higher net N-mineralization of organic nitrogen for all the three days of incubation. From these organic matters, 49.16 to 68.60% of organic nitrogen mineralized in 21 days, whereas, VC, RCD and FYM mineralized 12.57% to 13.72%. This difference in mineralization capacity may be attributed to the degree of stabilization of organic matters used in this experiment. Labile pool of organic nitrogen of VC and FYM might have been decreased due to their decomposition. However, PM exhibited very high nitrogen mineralization in spite of being decomposed. Flavel and Murphy (2006) also found very high gross nitrogen mineralization of palletized poultry manure along with high C-mineralization. RCD because of its high cellulose content exhibited low net nitrogen mineralization in spite of being un-decomposed.

Table 4: Cumulative net nitrogen mineralization of organic amendments (mg/kg soil) in leaching tube*

Organic matter	Days of incubation							
	7	14	21	28	35	42	49	56
VC	2.57	7.55	13.72	21.27	26.24	30.18	35.33	39.96
RCD	6.69	15.79	25.04	28.13	32.07	37.04	43.39	49.22
FYM	4.97	9.26	14.75	20.92	24.87	27.78	32.41	36.53
PM	13.89	25.04	37.73	46.65	54.71	60.37	67.74	73.74
FM	8.06	17.84	34.30	42.87	51.62	61.40	72.89	79.92
TW	15.95	29.33	42.70	53.34	65.17	76.32	87.81	97.07
MC	13.20	24.01	35.67	43.22	53.68	62.08	70.83	78.72

**Average of three replication.*

Aerobic nitrogen mineralization

Net nitrogen mineralization under aerobic condition was done in leaching tube and mineralized nitrogen was collected by leaching method in each week. It was planned to estimate the total mineralizable nitrogen of various organic matters for 8 weeks. The cumulative mineralized nitrogen data showed that the organic matter could be grouped into two- (i) having higher net organic nitrogen mineralization

Table 5: Correlation between C, N-mineralization and selected quality parameters of organic matters.

	N-min	C-min	ANI-7	ANI-14	ANI-21	WSOC	TON	TN %	C:N
N-min	1.00	0.781*	0.855*	0.972**	0.979**	0.805*	0.891**	0.892**	-0.849*
C-min		1.00	0.960**	0.888**	0.794*	0.885**	0.969**	0.972**	-0.773*
ANI-7			1.00.	-	-	0.844*	0.952**	0.963**	-0.769*
ANI-14				1.00	-	0.871*	0.959**	0.963**	-0.851*
ANI-21					1.00	0.812*	0.906**	0.901**	-0.927**
WSOC						1.00	0.936**	0.928**	-0.738
TON							1.00	0.999**	-0.862*
TN %								1.00	-0.853*
C:N									1.00

$^{**}p < 0.01$; $^{*}p < 0.05$.

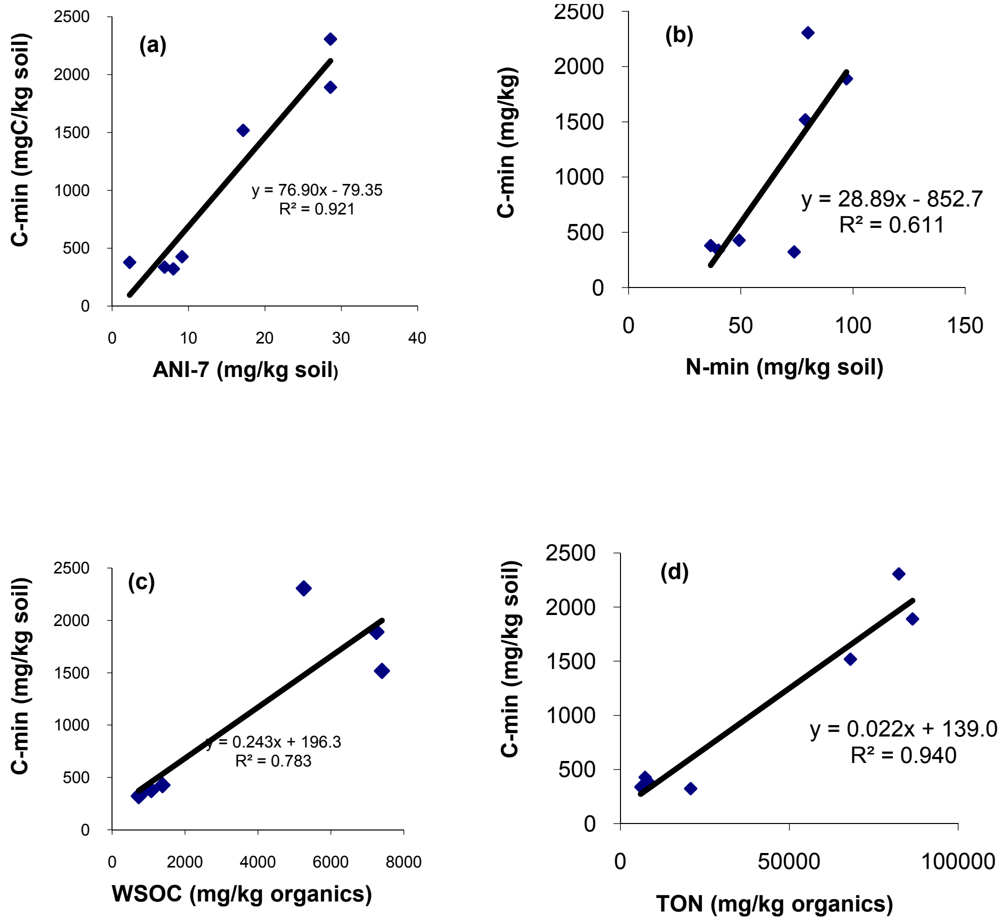

Fig. 1: Relationship between carbon mineralization with (a) anaerobic nitrogen mineralization index (NI-7), b) aerobic nitrogen mineralization, (c) water soluble organic nitrogen, (d) total organic nitrogen of organics

value ranging from 73.74 to 97.07 mgN/kg soil which include PM, FM, TW and MC, and (ii) the other having less net mineralization (36.53 to 49.22 mgN/kg) for VC, RCD and FYM (Table 3). Among the first group TW had the highest value (97.07) followed by FM (79.92), MC (78.72), and PM (73.74). Among VC, RCD and FYM, raw cow dung exhibited higher mineralization (49.22 mgN/kg soil) than VC (39.96 mgN/kg) FYM (36.53 mgN/kg).

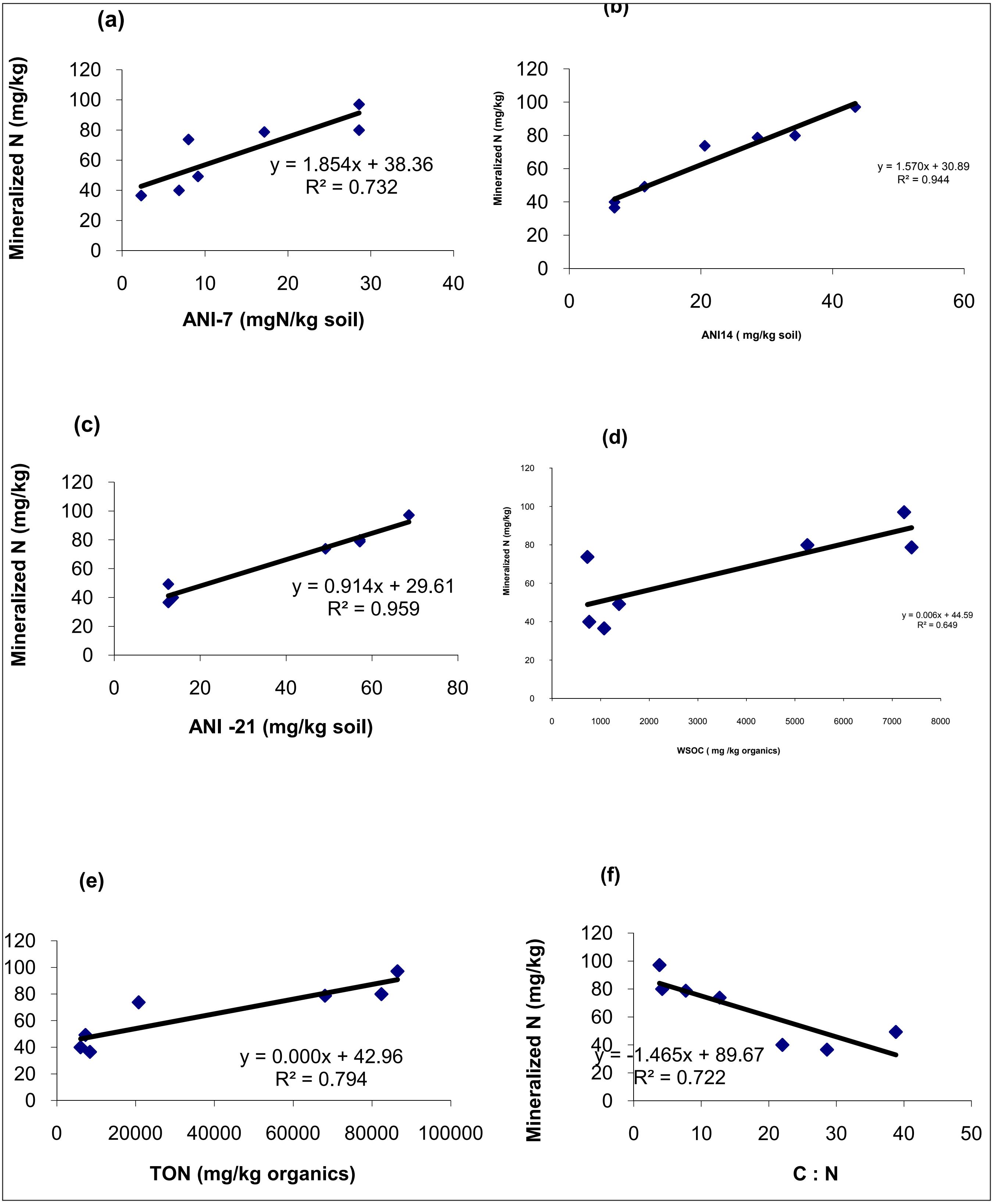

Fig. 2: Relationship between nitrogen mineralization with (a) anaerobic nitrogen mineralization index (NI-7), (b) ANI-14, (c) ANI-21, (d) Water soluble organic carbon (e) Total organic nitrogen and (f) C:N ratio of organics

Relation between quality of organic matters and C and N mineralization

Carbon mineralization was significantly correlated with total organic nitrogen (r=0.969**) and it had significant negative correlation with C: N ratio (r=0.774*) (Table 5). Linear regression analysis exhibited that carbon mineralization had a very high linear relation with total organic nitrogen (r^2=0.940) and water soluble organic carbon (r^2=0.7835) (Fig. 1).

Total mineralized nitrogen under aerobic condition was significantly correlated with amendment qualities like water soluble organic carbon (r=0.806*), total organic nitrogen (r=0.891**) and total nitrogen (r=0.892**) of organic matter (Table 5). As expected it was also negatively correlated with C: N ratio (r=0.850*). Linear relationship was also studied between nitrogen mineralization and other parameters with an objective to develop rapid indices for predicting mineralized nitrogen from organic matters (Fig. 2). It was observed that Aerobic nitrogen mineralization had linear relation with water soluble organic carbon (r^2=0.649), total organic nitrogen (r^2=0.795) and C: N ratio (r^2=0.722).

Relation between anaerobic nitrogen mineralization (ANI) and C and N mineralization

Anaerobic nitrogen mineralization index (ANI) was developed for three incubation period *i.e.* 7, 14 and 21 days considering the quality variation among organic matters. Carbon mineralization was significantly correlated with anaerobic nitrogen mineralization index i.e. ANI-7 (r=0.961**) (Table 5). Linear regression analysis exhibited that carbon mineralization had a very high linear relation with anaerobic mineralization index and 92.22% variation of carbon mineralization can be explained by nitrogen mineralization (Fig. 1). Aerobic nitrogen mineralization was also correlated with three anaerobic nitrogen index i.e. ANI-7, ANI-14 and ANI-21 with r value of 0.855*, 0.972**, 0.979**, respectively (Table 5).

Nitrogen mineralization (aerobic) when regressed against anaerobic nitrogen index i.e. ANI-7, ANI-14 and ANI-21, R^2 value of 0.733, 0.945 and 0.960 were found, respectively, indicating that anaerobic nitrogen mineralization index can be a useful tool for predicting nitrogen mineralizing capacity of various organic matters. The R^2 value also reveals that higher days of incubation had better fit with nitrogen mineralization. In this context it is to mention that Scott *et al.,* (2005) got poor relation (R^2=0.46) between nitrogen mineralization and anaerobic nitrogen index, but incubated period was for 7 days.

In a laboratory experiment Qafoku *et al.* (2001) observed that up to 78.6% of organic nitrogen was mineralized from poultry manure. Mineralization processes involved in the N cycle are biotic and the processes is higher in soils with a higher microbial biomass and activity (Bengtsson *et al.,* 2003), providing other factors are the same. In the peletized poultry manure amended soils the highest gross N mineralization rates were obtained on the same days as the high MB-C and CO_2-C evolution rates were recorded (Flavel and Murphy, 2006). But in the present investigation it was found that in case of FM, which exhibited very high carbon and nitrogen mineralization, high C-mineralization at initial stage was accompanied with less net N-mineralization. However, this was not the case in all treatments. This may be due to the quality of C and N in the organic amendment, or because the proportion of the microbial biomass that is active in each amended soil is different.

CONCLUSION

The aim of this study was to evaluate the performance of chemical and biological indices that can predict the carbon and nitrogen of mineralization of organic matters having various degrees of stabilization and variable amount of carbon and nitrogen. We found that water soluble organic carbon and short term N-mineralization under waterlogged condition (anaerobic) at high temperature could be considered as reliable indices for carbon and nitrogen mineralization form organic matters. It should be kept in mind, however, that the results were obtained with samples that were sieved and the experiments were conducted under laboratory condition. Further studies are needed to test both the indices for measuring C and N mineralization from unprocessed organic matters under field condition.

ACKNOWLEDGEMENTS

This research programme was funded by Tea

Board, Government of India. We are thankful to the chairman, Tea Board and the director (Research), Tea Board for providing the financial support.

REFERENCES

Bengtsson, G., Bengtson, P. and Mansson, K.F. 2003. Gross nitrogen mineralization-, immobilization, and nitrification rateds as a function of soil C: N ratio and microbial activity. *Soil Biology and Biochemistry* **35**:143-154.

Bernal, M.P., Sanchez-Monedero, C. Pardes, C. and Roig, A. 1998c. Carbon moneralization from organic wastes at different composting stages during their incubation with soil. *Agric. Ecosyst. Environ*. **69**: 175-189.

Bernal, M.P., Pardes, C., Sanchez-Monedero, M.A. and Ceggara, J. 1998b. Maturity and stability parameters of composts prepared with a wide range of organic wastes. *Bioresour. Technol*. **63**: 91-99.

Bitzer, C.C. and Sims, J.T. 1988. Estimating the availability of nitrogen in poultry manure through laboratory and field studies. *Journal of Environmental Quality* **17**: 47-54.

Castellanos, J.Z. and Pratt, P.F. 1981. Mineralization of manure nitrogen – correlation with laboratory indexes. *Soil Science Society American Journal* **45**: 354-357.

Chae, Y.M. and Tabatabai, M.A. 1986. Mineralization of nitrogen in soils amended with organic wastes. *Journal of Environmental Quality* **15**: 193-198.

Chambers, B.J., Lord, E.I., Nicholson, F.A. and Smith, K.A. 1999. Predicting nitrogen availability and losses following application of organic manures to arable land: *MANNER, Soil Use Manage* **15**:137–143.

Douglas, B.F. and Magdoff, F.R. 1991. An evaluation of nitrogen mineralization indices for organic residues. *Journal of Environmental Quality* **20**: 368-372.

Flavel, T.C. and Murphy, D.V. 2006. Carbon and nitrogen mineralization rates after application of organic amendments to soil. *Journal of Environmental Quality* **35**: 183-193.

Gigliotti, G., Kaiser, K. Guggenberger, G. and Haumaier, L. 2002. Differences in the chemical composition of dissolved organic matter from waste material of different sources. *Biol. Fertil. Soils* **36**: 321-329.

Goulding, K.W.T., Murphy, D.V., Macdonald, A., Stockdale, E.A., Gaunt, J.L., Blake, L., Ayaga, G. and Brookes, P. 2001. The role of soil organic matter and manures in sustainable nutrient cycling, in: Rees R.M., Ball B.C., Campbell C., Watson C.A. (Eds.), Sustainable Management of Soil Organic Matter, CABI Oxford, pp. 221–232.

Haynes, R.J. and Francis, G.S. 1993. Changes in microbial biomass C, soil carbohydrate composition and aggregate stability induced by growth of selected crop and forage species under field conditions. *Journal of Soil Science* **44**: 665-675.

Jackson, M.L. 1973. Soil Chemical Analysis. Prentice Hall, New Delhi.

Keeney, D.R. 1982. Nitrogen availability indices. In: Methods of soil analysis. Part 2: Chemical and Microbial Properties. (Eds. C. A. Black *et al.*). American Society of Agronomy Madison. *Wisconsin. USA, pp*. 711-733.

Kirchmann, H. 1991. Carbon and nitrogen mineralization of fresh, aerobic and anaerobic animal manures during incubation with soil, *Swed. J. Agric. Res*. **21**:165–173.

Nelson, D.W. and Sommers, L.E. 1982. Total Carbon, Organic Carbon and Organic Matter. pp. 539-594. In: A.L. Page *et al*. (ed.) Methods of soil analysis, part 2. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI.

Qafoku, O.S., Cabrera, M.L., Windham, W.R. and Hill, N.S. 2001. Rapid methods to determine potentially minera1izable nitrogen in broiler litter. *Journal of Environmental Quality* **30**: 217-221.

Scott, D.A., Norris, A.M. and Burger, J.A. 2005. Rapid indices of potential nitrogen mineralization for intensively managed hardwood plantations. *Communication in Soil Science Plant Analysis*. **36**: 1421-1434.

Serna, M.D. and Pomares, F. 1991. Comparison of biological and chemical methods to predict nitrogen mineralization in animal wastes. *Biol. Fertil. Soils* **12**: 89-94.

Stanford, G. and Smith, S.J. 1972. Nitrogen mineralization potentials. *Soil Science Society of American Proceedings* **38**: 99-102.

Stockdale, E.A. and Rees, R.M. 1995. Release of nitrogen from plant and animal residues and consequent plant uptake efficiency, *Biol. Hortic. Agric* **11**: 229–245.

Waring, S.A. and Bremner, J.M. 1964. Ammonium production in soil under waterlogged condition as an index of nitrogen availability. *Nature* **201**: 951-952.

Wang, W.J., Baldock, J.A. Dalal, R.C. and Moody, P.W. 2004b. Decomposition dynamics of plant materials in relation to nitrogen availability and biochemistry determined by NMR and wet-chemical analysis. *Soil Biol. Biochem*. **36**:2045-2058.