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Influence of Organic Manures and Moisture Regimes on Hydrolysable Forms of Nitrogen in an Acid Soil of Manipur, India

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ABSTRACT

A laboratory experiment was conducted to study the changes in some hydrolysable organic forms of nitrogen in an acid soil treated with different organic manures *viz*., vermicompost (paddy straw and vegetable waste), farmyard manure (FYM) and biogas manure as nitrogen sources @ equivalent to 50 mg N kg^{-1} soil at different moisture regimes *viz*., 40%, 60% and 80% water holding capacity (WHC). Results revealed that irrespective of different organic manure treatments, the significantly higher amount of all the hydrolysable organic nitrogen fractions (hydrolysable NH_4^+, amino acid, hexosamine and serine + threonine) - N was found at 80% WHC than 40% and 60% WHC. Variable trends of these different organic fractions of N showed that these N forms were affected by moisture regimes. Greater amount of different organic forms of nitrogen were accumulated in organic matter treated system than untreated one irrespective of moisture regimes and incubation period. Among the organic manures, soil amended with vermicompost (paddy straw) showed comparatively greater accumulation of different hydrolysable organic N fractions than other organic manures. The extent of changes in different forms of organic N fractions varied with nitrogen fractions, organic matter and moisture regimes.

Introduction

Nitrogen (N) is one of the most important plant nutrient required by plants for growth and metabolic activities. It also encourages vegetative growth. It is required in relatively large concentration by most agricultural crops, but only insufficient quantities are available in the soil. Nitrogen is the most common limiting nutrient in crop production. In soil, nitrogen exists in two major forms: organic and inorganic. A bulk of total nitrogen is present in the organic form and only about 2% in inorganic form. The organic form of nitrogen, particularly the hydrolysable form, is slowly mineralized and is transformed to mineral nitrogen by soil microbes. However, some organic nitrogen is in the forms that are difficult for microbes to digest and release under any circumstance. During the transformation nitrogen is converted from one form to another.

Nitrogen, present in soil, mostly comes from natural sources and applied fertilizers. However, both the sources are important for growing crops. But the addition of organic manures is of utmost importance with respect to maintenance of soil fertility as a whole and controlled release of nitrogen during cropping season in particular. The status of organic nitrogen fractions in soil can be determined by hydrolyzing the soil with 6N HCl. Bremner (1965) reported that more than 95% of the total N was in organic combination, a portion of which, on hydrolysis, is liberated as ammonium (10-25%), a greater portion as amino acids (25-40%) and a smaller fraction as amino sugar (1-5%). These hydrolysable N fractions are the main source of the availability of N for the nutrition of organisms in soil.

Nitrogen transformation in soil is influenced by organic matter additions (Sihag *et al.*, 2005 and Abbasi *et al.*, 2007), its sources and state of decomposability (Khalil *et al.*, 2001). Many biotic and abiotic factors such as moisture, temperature and nutrient addition drastically affect the decomposition of organic materials added to soil. Among abiotic factors, soil moisture content has great impact on the decomposition and transformation of nutrients (Doel *et al.*, 1990) and is the most important factor that regulates the accumulation of different hydrolysable organic fractions of nitrogen from transformation processes (Khalil *et al.*, 2001; Wang *et al.*, 2006 and Guntinas *et al.*, 2012). Considering the above points, the present study was undertaken with the objective "to study the changes in different hydrolysable organic fractions of nitrogen in soil amended with organic manures under different moisture regimes".

Materials and Methods

Surface (0-15 cm depth) soil samples from paddy field of Manipur, India were collected for the laboratory experiment. The samples were air dried in shade, crushed and sieved through 2mm sieve. The relevant physicochemicals properties of the soil were presented in Table 1. Organic manures from different sources *viz*. farmyard manure (FYM), vermicompost (both from paddy straw and vegetable waste) and biogas manure were collected to study the effect of these manures on hydrolysable organic N fractions in the soil at three moisture regimes: 40%, 60% and 80% water holding capacity (WHC). The total nitrogen content of the organic manures are FYM -1.1%, vermicompost (paddy straw) -1.3%, vermicompost (vegetable waste) -1.4% and biogas manure -1.5%, respectively. Soil texture, water holding capacity (WHC), pH, EC, organic carbon, cation exchange capacity (CEC), available N, P and K were determined following the standard procedure described by Jackson (1973).

The concentration of different hydrolysable forms of organic N *viz*., hydrolysable NH_4^+ -N, hexosamine N, amino acid N and (serine+threonine) - N following acid hydrolysis method using 6N hydrochrolic acid (Bremner, 1965) were analysed. The treatments used in the study were T_1 =Soil (Control), T_2 = Soil + Farmyard manure (FYM), T_3 = Soil + Vermicompost (paddy straw), T_4 = Soil + Vermicompost (vegetable waste) and T_5 = Soil + Biogas manure. Different organic manures were given at the rate equivalent to 50 mg N kg^{-1} soils of each treatment in 10 g soil taken in 100 ml beaker. The treatments were moistened to 40%, 60% and 80% of water holding capacity (WHC) and kept at room temperature (30± 2) throughout the experiment. The loss of moisture was replenished by the periodic addition of sterile distilled water on every alternate day by difference in weight. The beakers were kept covered with black polythene sheet and incubated for a period of 90 days. Then, the soil samples were periodically collected and analyzed for hydrolysable organic NH_4^+, hexosamine N, amino acid N and (serine+threonine) - N contents at 0th, 15th, 30th, 45th, 60th, 75th and 90th days of incubation. Separate sets of treatments were maintained for each of the sampling stages.

The experiment was carried out under factorial randomized block design (FRBD). Altogether there were 15 treatment combinations replicated thrice.

Results and Discussion

Hydrolysable organic NH_4^+-N

The results showed that the trend of changes in the amount of hydrolysable organic NH_4^+ occurred differently at different moisture levels (Table 2 and Fig. 1). On an average, its accumulation was slightly higher on 90th day over 0th day of incubation (Table 2). This may be due to immobilization of inorganic N in soil (Gupta *et al.*, 2003 and Sihag *et al.*, 2005). In general, among the different moisture regimes, accumulation of hydrolysable organic NH_4^+-N was significantly higher in 80% WHC than 40% and 60% WHC showing that hydrolysable NH_4^+-N content gradually increased up to the end of the incubation except in vermicompost (paddy straw) treated soil which showed slight decrease on 30th day (Table 2 and Fig. 1c). The increase in the amount of hydrolysable organic NH_4^+ was due to conversion of other forms of inorganic or organic N to this form of N whereas the decrease in soil may be due to mineralization of this fraction of organic N under favourable microclimate (Mohapatra, 1988).

This conversion of one form to other form of N during mineralization and immobilization processes was also reported by Gupta *et al.*, (2003). Closer examination of the results (Table 2) revealed that organic manures released hydrolysable organic NH_4^+ in soils leading to higher order of hydrolysable NH_4^+ in organic matter treated over untreated systems at different stages of incubation (Sharma *et al.*, 1992 and Sihag *et al.*, 2005). This fraction registered a significant increase due to organic matter addition over their respective initial status (Tabassum *et al.*, 2010). Irrespective of different moisture regimes, significantly higher amount of hydrolysable NH_4^+-N accumulation was observed in soil treated with vermicompost (paddy straw) followed by biogas manure on 90th day of experiment at 80% WHC (Table 2 and Fig. 1c). This indicated that immobilization processes were depended on the nature of the organic amendments their degree of stability and moisture regimes. The results are at par with the earlier works of Jedidi *et al.*, (1995) and Olayanka (2001).

Hexosamine N

Results revealed that irrespective of treatments, more or less similar trend of hexosamine N accumulation was observed showing gradual increase up to the end of experiment excepting that hexosamine N decreased slightly on 45th and 30th day at 40% (Fig. 2a) and 80% WHC (Fig. 2c), respectively. The increase was more pronounced at higher moisture level with significantly higher concentration at 80% WHC followed by 60% and 40% WHC (Table 3). The rapid mineralization of organic N accelerates the decrease in hexosamine N in soils. Addition of more water influenced the conversion of other forms of inorganic or organic N to hexosamine N throughout the incubation period to a greater extent. Irrespective of different moisture regimes, results (Table 3) pointed out that significantly higher amount of hexosamine N was accumulated in all the organic manure treated soils in comparison to control at different stages of incubation. The result was also supported by the earlier reports of Gotoh *et al.*, (1986); Sharma *et al.*, (1992); Sihag *et al.*, (2005) and Qian-Ru *et al.*, (2009).

Table.1 General characteristics of the soil used in the experiment

Soil characteristics		Results
Textural class	:	Silty Clay
Sand (%)	:	11.20
Silt (%)	:	40.00
Clay (%)	:	48.80
Maximum water holding capacity (%)	:	59.63
pH (1:2.5 soil:water ratio)	:	5.20
EC (1:2.5 soil:water ratio, dsm^{-1})	:	0.21
CEC [$cmol(p^+)kg^{-1}$]	:	13.40
Organic carbon (%)	:	1.20
Available nitrogen ($mg\ kg^{-1}$)	:	154.02
Available phosphorus ($mg\ kg^{-1}$)	:	12.50
Available potassium ($mg\ kg^{-1}$)	:	64.73

Table.2 Hydrolysable organic NH_4^+ ($mg\ kg^{-1}$) in soil amended with organic manures at different moisture regimes

Treatments		Days incubated						
Moisture	Organic manures	0	15	30	45	60	75	90
M_1 (40% WHC)	T_1	256.50	249.50	255.00	261.00	275.50	280.50	290.00
	T_2	260.50	269.55	273.00	280.50	283.50	300.45	299.10
	T_3	277.00	288.00	295.50	292.50	294.00	300.00	305.40
	T_4	262.00	279.00	294.00	292.50	294.00	304.50	303.00
	T_5	272.50	271.50	289.50	294.00	291.00	308.55	300.00
M_2 (60% WHC)	T_1	255.00	280.00	291.55	295.75	287.50	294.50	280.00
	T_2	262.00	286.00	304.00	304.00	296.05	303.85	295.00
	T_3	272.00	290.50	306.25	312.25	302.50	317.50	297.40
	T_4	266.00	290.50	309.85	310.00	311.50	308.95	291.25
	T_5	271.50	287.50	309.10	306.55	296.05	314.80	297.55
M_3 (80% WHC)	T_1	256.50	294.85	305.00	310.50	310.00	323.50	340.50
	T_2	265.50	305.50	318.55	324.40	337.90	356.50	379.00
	T_3	275.00	340.75	321.85	335.35	358.00	376.00	398.50
	T_4	266.50	303.85	322.00	335.50	340.50	358.60	370.00
	T_5	273.90	318.25	320.50	326.50	349.00	361.00	383.50
Treatment effect (Mean values)	T_1	256.00	274.78	283.85	289.08	291.00	299.50	303.50
	T_2	262.67	287.02	298.52	302.97	305.82	320.27	324.37
	T_3	274.67	306.42	307.87	313.37	318.17	331.17	333.77
	T_4	264.83	291.12	308.62	312.67	315.33	324.02	321.42
	T_5	272.63	292.42	306.37	309.02	312.02	328.12	327.02
Moisture effect (Mean values)	M_1	265.70	271.51	281.40	284.10	287.60	298.80	299.50
	M_2	265.30	286.90	304.15	305.71	298.72	307.92	292.24
	M_3	267.48	312.64	317.58	326.45	339.08	355.12	374.30
CD ($_{0.05}$)	T	1.58	1.31	2.27	1.32	1.36	0.98	1.38
	M	NS	0.78	1.36	0.79	0.82	0.74	1.04
	TxM	NS	3.92	6.81	3.96	4.09	2.95	4.15

Table.3 Hexosamine N (mg kg^{-1}) in soil amended with organic manures at different moisture regimes

Treatments		Days incubated						
Moisture	Organic manures	0	15	30	45	60	75	90
M_1 (40% WHC)	T_1	87.60	87.33	94.00	99.45	102.00	116.67	120.67
	T_2	88.60	100.47	105.53	102.87	110.00	124.00	126.67
	T_3	94.00	98.00	103.13	105.13	114.67	132.67	134.00
	T_4	90.00	102.67	107.80	105.80	108.67	128.67	130.67
	T_5	92.60	104.87	108.47	106.67	114.67	133.33	133.33
	T_1	88.30	103.33	110.67	115.00	120.66	124.67	132.00
	T_2	90.60	110.00	118.00	120.67	123.33	134.00	134.67
M_2 (60% WHC)	T_3	91.30	115.33	117.33	128.00	135.33	144.00	144.67
	T_4	93.30	112.67	117.33	123.33	130.67	140.00	138.00
	T_5	91.30	113.33	121.33	124.00	135.33	138.00	144.00
	T_1	87.00	110.00	98.00	117.00	124.00	124.67	136.00
	T_2	88.60	115.33	113.60	126.67	134.67	136.00	141.33
M_3 (80% WHC)	T_3	95.00	116.67	118.00	124.60	141.33	144.00	150.00
	T_4	89.00	118.00	117.33	126.67	133.33	140.67	145.33
	T_5	90.00	115.07	117.73	130.00	136.00	140.00	146.67
Treatment effect (Mean values)	T_1	87.63	100.22	100.89	110.48	115.55	122.00	129.56
	T_2	89.27	108.60	112.38	116.73	122.67	131.33	134.22
	T_3	93.43	110.00	112.82	119.24	130.44	140.22	142.89
	T_4	90.77	111.11	114.16	118.60	124.22	136.44	138.00
	T_5	91.30	111.09	115.84	120.22	128.67	137.11	141.33
Moisture effect (Mean values)	M_1	90.56	98.67	103.79	103.98	110.00	127.07	129.07
	M_2	90.96	110.93	116.93	122.20	129.07	136.13	138.67
	M_3	89.92	115.01	112.93	124.99	133.87	137.07	143.87
CD $(_{0.05})$	T	0.54	1.01	0.82	0.72	0.95	0.88	0.73
	M	NS	0.61	0.49	0.43	0.57	0.53	0.44
	TxM	1.63	NS	2.45	2.15	NS	2.64	2.19

Table.4 Amino acid N ($mgkg^{-1}$) in soil amended with organic manures at different moisture regimes

Treatments		Days incubated						
Moisture	Organic manures	0	15	30	45	60	75	90
M_1 (40%WHC)	T_1	378.50	390.50	400.50	421.50	426.00	441.00	450.00
	T_2	383.50	396.00	423.00	438.00	453.00	451.50	465.00
	T_3	396.50	408.00	435.00	450.00	456.00	462.00	472.50
	T_4	391.00	405.00	421.50	441.00	462.00	457.50	463.50
	T_5	394.00	409.50	427.50	441.00	462.00	460.50	468.00
M_2 (60%WHC)	T_1	378.00	405.00	410.00	402.00	436.00	445.00	480.00
	T_2	389.00	418.00	422.50	433.00	449.50	452.50	485.50
	T_3	398.00	424.00	436.00	439.00	452.50	469.00	491.50
	T_4	390.00	418.00	419.50	433.00	452.50	452.50	490.00
	T_5	396.50	424.00	436.00	436.00	448.00	458.50	491.50
M_3 (80%WHC)	T_1	375.50	447.50	460.00	435.00	438.00	477.50	477.50
	T_2	386.00	494.00	500.00	460.50	472.00	491.00	491.00
	T_3	395.50	501.50	506.00	477.00	488.50	507.50	509.00
	T_4	389.00	495.50	508.00	470.00	480.50	510.50	509.00
	T_5	394.00	497.00	500.00	465.00	479.50	510.50	498.50
Treatment effect (Mean values)	T_1	377.33	414.33	423.50	419.50	433.33	454.50	469.17
	T_2	386.17	436.00	448.50	443.83	458.17	465.00	480.50
	T_3	396.67	444.50	459.00	455.33	465.67	479.50	491.00
	T_4	390.00	439.50	449.67	448.00	465.00	473.50	487.50
	T_5	394.83	443.50	454.50	447.33	463.17	476.50	486.00
Moisture effect (Mean values)	M_1	388.70	401.80	421.50	438.30	451.80	454.50	463.80
	M_2	390.30	417.80	424.80	428.60	447.70	455.50	487.70
	M_3	388.00	487.10	494.80	461.50	471.70	499.40	497.00
$CD_{(0.05)}$	T	1.10	1.11	2.37	1.32	1.40	1.36	1.44
	M	NS	0.66	1.42	0.79	0.84	0.82	0.87
	TxM	NS	3.32	7.11	3.97	4.19	4.08	4.33

Table.5 Serine + threonine-N (mg kg^{-1}) in soil amended with organic manures at different moisture regimes

Treatments		Days incubated						
Moisture	Organic manures	0	15	30	45	60	75	90
M_1 (40%WHC)	T_1	204.67	209.00	211.00	208.67	214.33	205.33	211.33
	T_2	206.00	212.33	216.00	217.67	226.33	228.00	229.00
	T_3	210.33	215.00	222.33	221.00	230.33	232.67	230.67
	T_4	206.67	212.33	219.00	217.33	227.00	229.00	230.00
	T_5	207.00	210.67	216.67	221.33	229.00	230.00	231.67
M_2 (60%WHC)	T_1	205.67	209.67	209.67	210.67	216.33	217.33	213.67
	T_2	208.67	215.00	221.00	222.00	227.00	238.00	238.00
	T_3	210.33	214.67	223.33	223.67	234.00	240.33	239.67
	T_4	208.67	210.33	222.00	223.67	231.33	240.00	237.33
	T_5	210.33	220.67	222.33	224.00	229.33	236.33	241.33
M_3 (80%WHC)	T_1	208.67	213.67	214.00	218.33	225.33	219.67	221.67
	T_2	208.33	216.33	218.67	221.33	227.67	229.67	233.33
	T_3	209.33	222.33	221.33	223.67	230.33	234.33	238.00
	T_4	208.67	218.67	217.33	223.00	229.00	231.00	236.67
	T_5	209.33	219.33	223.33	223.67	229.33	231.67	237.67
Treatment effect (Mean values)	T_1	206.34	210.78	211.56	212.56	218.67	214.11	215.56
	T_2	207.67	214.56	218.56	220.33	227.00	231.89	233.44
	T_3	210.00	217.33	222.33	222.78	231.56	235.78	236.11
	T_4	208.00	213.78	219.44	221.33	229.11	233.33	234.67
	T_5	208.89	216.89	220.78	223.00	229.22	232.67	236.89
Moisture effect (Mean values)	M_1	206.93	211.87	217.00	217.20	225.40	225.00	226.53
	M_2	208.73	214.07	219.67	220.80	227.60	234.40	234.00
	M_3	208.87	218.07	218.93	222.00	228.33	229.27	233.47
CD $(_{0.05})$	T	0.82	0.83	1.03	0.64	0.81	0.83	0.90
	M	0.49	0.50	NS	0.38	0.48	0.50	0.54
	TxM	NS	2.50	3.09	1.92	2.42	2.50	2.69

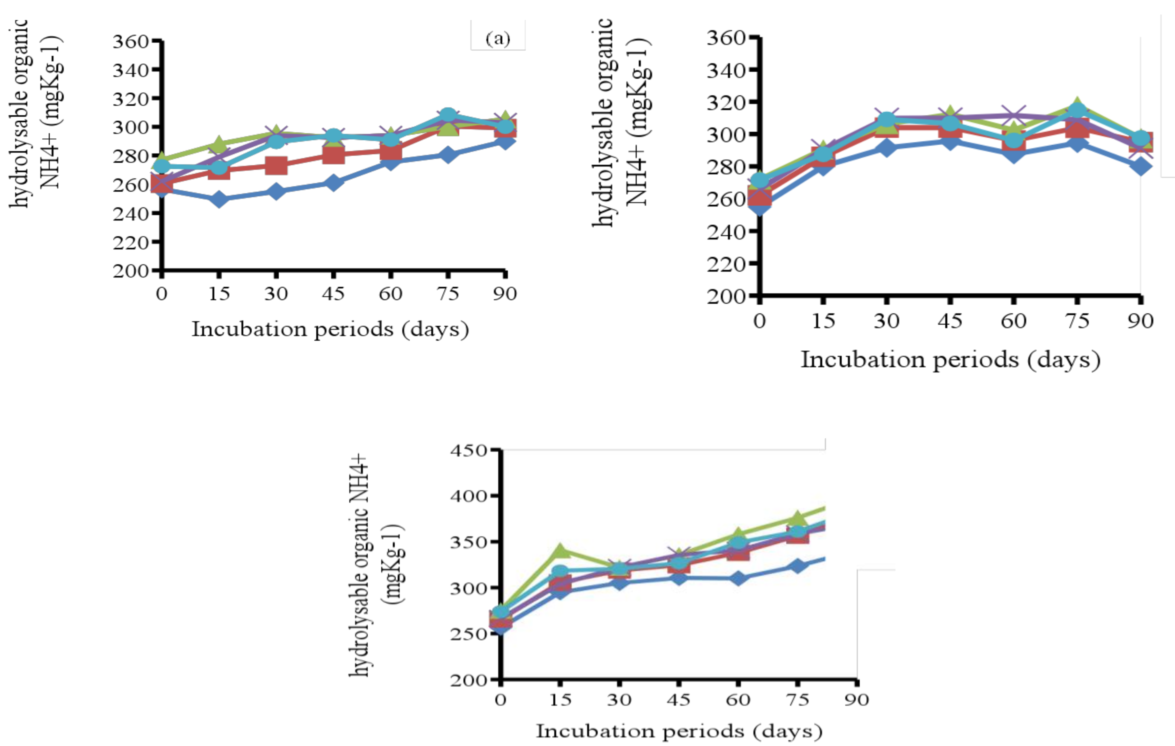
The increase in accumulation of hexosamine N in soil amended with organic manures is perhaps due to conversion of inorganic and organic N to this form of hydrolysable organic N. Again, the release of hexosamine N is significantly more in vermicompost (paddy straw) from 60th day onwards till the end of the experiment at 80% WHC (Table 3 and Fig. 2).

Amino acid N

Under the investigation, variable trends of amino acid concentrations at 40%, 60% and 80% WHC (Table 4 and Fig. 3) showed that this fraction of N was affected by the moisture regimes and observed that significantly higher amount of amino acid N was accumulated in 80% WHC showing a different pattern with sharp increase up to 15th followed by slight increase on 30th day, then gradually decreased till 60th day and thereafter increased slightly up to 90th day excepting vermicompost (vegetable waste) and biogas manure treated soils showing decline at the end of the incubation (Table 4 and Fig. 3c).

However, in case of 40% and 60% WHC, there was significantly gradual increase of amino acid N in soils up to the end of the experiment excepting a slight decrease on 75th day in soils treated with vermicompost (vegetable waste), farmyard manure and biogas manure at 40% WHC (Table 4 and Fig. 3a).

Fig.1 Changes in the amount of hydrolysable organic NH_4^+ (mg kg^{-1}) in soil amended with organic manures at (a) 40% WHC, (b) 60% WHC and (c) 80% WHC



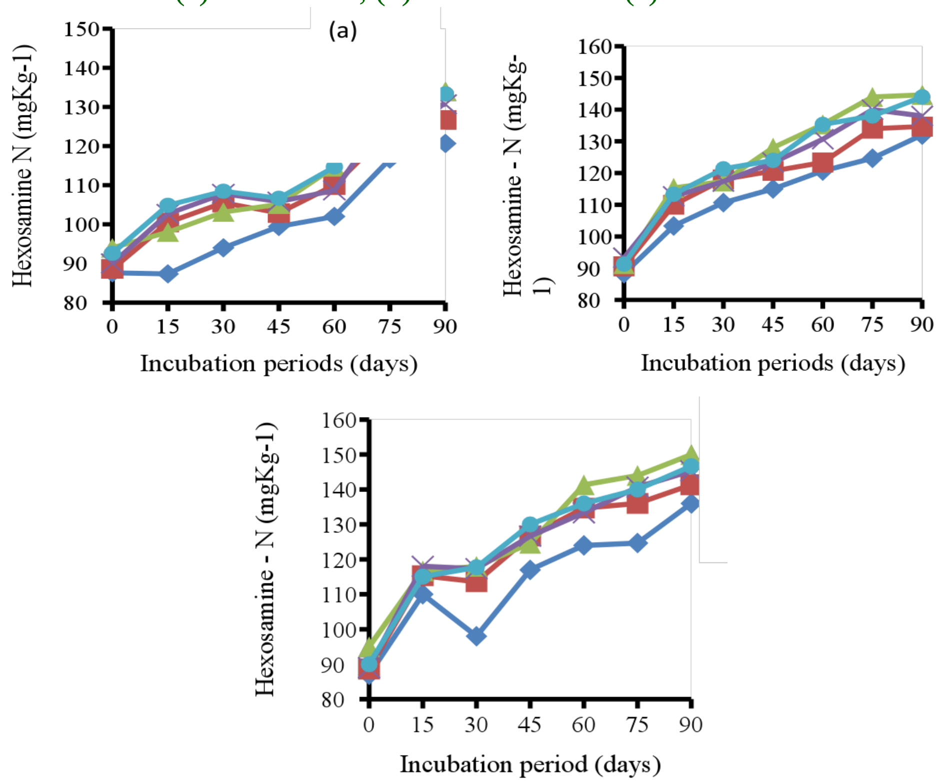
Treatments: ♦, Control (untreated); ■, Farmyard manure; ▲, Vermicompost (paddy straw); X, Vermicompost (vegetable waste); ●, Biogas manure

The sudden increase in the amount of amino acid N was perhaps due to conversion of other forms of N to this form. Although no significant variation was observed in the amino acid N content in soil under different moisture regimes at the initial day of incubation, a significant variation was noticed at other stages. Irrespective of moisture regimes, addition of organic manure (Table 4) played a significant role in production of amino acid N in soils (Gotoh *et al.*, 1985; Sharma *et al.*, 1992; Sihag *et al.*, 2005 and Qian-Ru *et al.*, 2009). The magnitude of accumulation of amino acid fraction was more in soil amended with vermicompost (paddy straw) as compared to other organic manures at the final stages of incubation (Table 4 and Fig. 3). This is due to conversion of other forms of hydrolysable organic N to amino acid fraction.

(Serine+threonine)-N

Changes in the amount of (serine+threonine)-N in soil treated with organic manures at different moisture regimes are presented in Table 5 and Figure 4. The Figure showed that irrespective of different treatments and incubation stages, (serine+threonine)-N did not follow any definite trend at different moisture levels. Although (serine+threonine) was a part of amino acid N, the immobilization process of both the forms of N was different. Critical study showed that at 40% and 60% WHC, (serine+threonine)-N increases gradually in organic manure treated systems up to the end with exception of slight decrease in vemicompost (both paddy straw and vegetable waste) amended soils on 45th and 90th day (Fig. 4a and 4b).

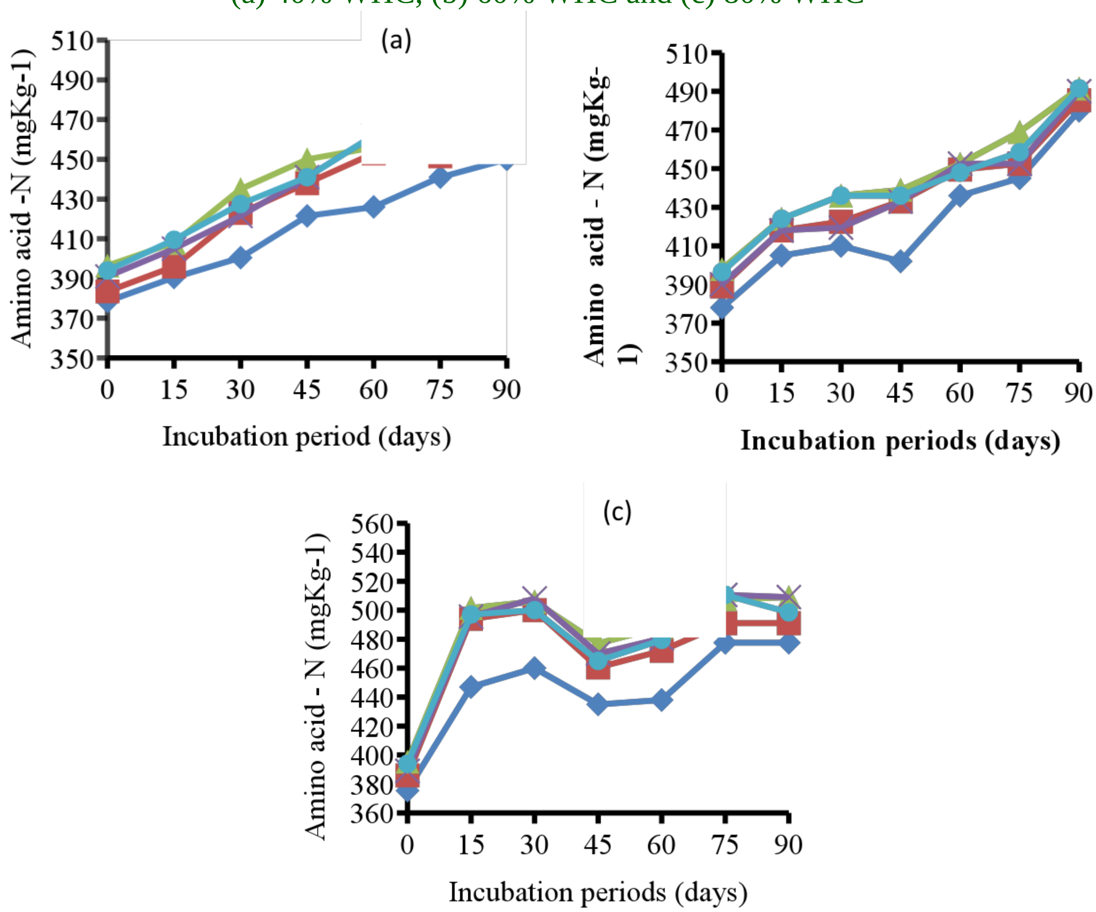
Fig.2 Changes in the amount of hexosamine N (mg kg^{-1}) in soil amended with organic manures at (a) 40% WHC, (b) 60% WHC and (c) 80% WHC



Treatments: ♦, Control (untreated); ■, Farmyard manure; ▲, Vermicompost (paddy straw); X, Vermicompost (vegetable waste); ●, Biogas manure

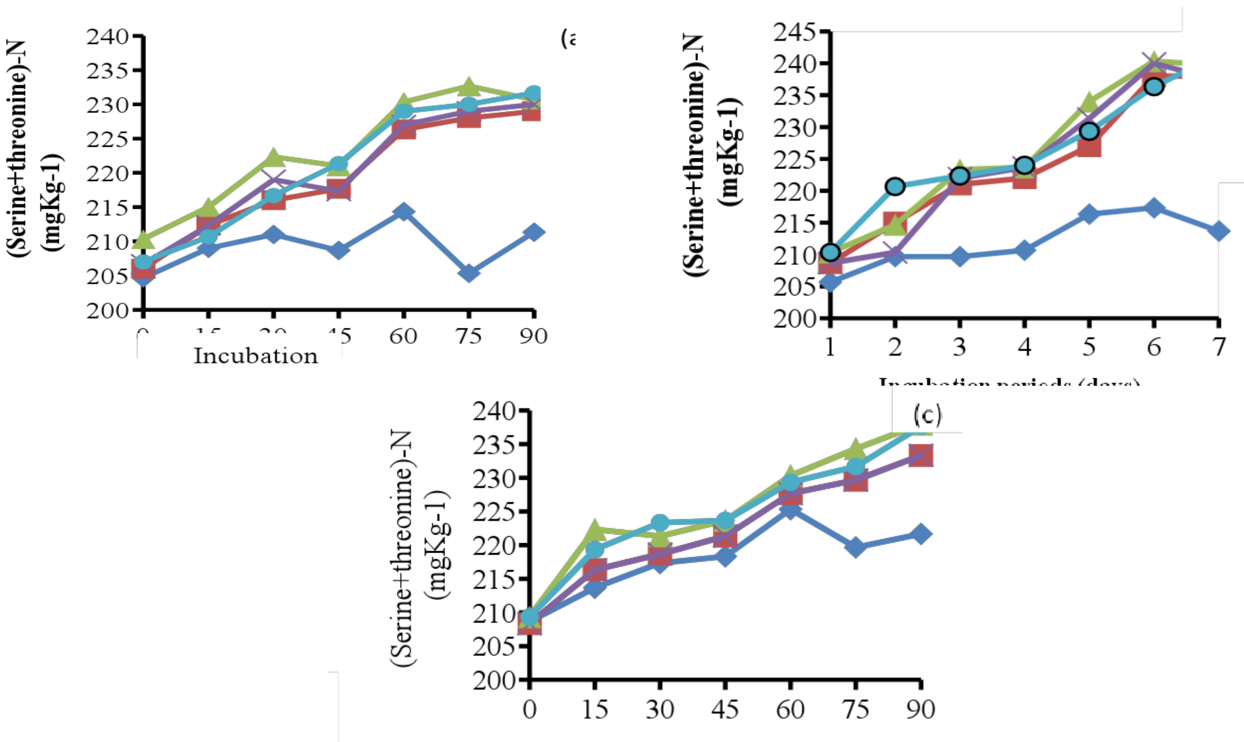
Further study revealed an increasing trend of the organic N fraction at 80% WHC up to the final stage of incubation with a slight decline on 30th day in soils treated with vermicompost (both paddy straw and vegetable waste, Fig 4c). The increase and decrease in (serine+threonine)-N over 90 days period is perhaps due to unstability of these fractions of amino acid in soil. Significantly higher amount of (serine+threonine)-N was accumulated in soils maintained at 80% WHC followed by 60% WHC on 15th, 45th and 60th day of incubation. However, at the end of the experiment, the effect of 60% WHC was at par with 80% WHC. Addition of organic manures (Table 5) also encouraged to accumulate significantly higher amount of (serine+threonine)-N than untreated system (Gotoh *et al.*, 1985; Sharma *et al.*, 1992; Sihag *et al.*, 2005 and Qian-Ru *et al.*, 2009). A comparison of the results of different organic treatments revealed that the amount of (serine+threonine)-N was significantly higher in soil treated with vermicompost (paddy straw) on 30th, 60th and 75th day of incubation (Fig. 4, Table 5). However, at the end of the incubation study soil treated with vermicompost (paddy straw) is at par with biogas manure followed by vermicompost (vegetable waste) and farmyard manure (FYM) treated soils showing immobilization processes were depended on the nature of the organic amendments and their degree of stability (Jedidi *et al., 1995* and Olayanka, 2001).

Fig.3 Changes in the amount of amino acid N (mgkg^{-1}) in soil amended with organic manures at (a) 40% WHC, (b) 60% WHC and (c) 80% WHC



Treatments: ♦, Control (untreated); ■, Farmyard manure; ▲, Vermicompost (paddy straw); X, Vermicompost (vegetable waste); ●, Biogas manure

Fig.4 Changes in the amount of (Serine+threonine)-N (mg kg^{-1}) in soil amended with organic manures at (a) 40% WHC, (b) 60% WHC and (c) 80% WHC



Treatments: ♦, Control (untreated); ■, Farmyard manure; ▲, Vermicompost (paddy straw); X, Vermicompost (vegetable waste); ●, Biogas manure

From the investigation carried out, it could be concluded that the extent of changes of different organic N fractions varied with N fractions, organic matter sources and moisture regimes. Accumulation of different hydrolysable organic N fractions including hydrolysable organic NH_4^+, amino acid N, hexosamine-N and (serine+threonine)-N were significantly higher at 80% WHC over 40% and 60% WHC showing greater immobilization at higher moisture level. Among the different organic manures, comparatively higher amount of all the different fractions of N were accumulated in vermicompost (paddy straw) treated soil. Application of organic manures is an effective way of maintaining the quantity and quality of soil organic N. The traditional use of manures should therefore, be promoted in order to maintain long term soil productivity. Changes in soil moisture due to management of water resources will affect hydrolysable organic fractions of nitrogen. So, before using different sources of organic manures in the field due consideration should be given on immobilization processes of those organic manures as well as moisture status.

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