

Influence of Different Organic Waste Materials on the Transformation of Nitrogen in Soils

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Organic waste materials like crop residues, well-decomposed cow dung, composts, and other rural and urban wastes are considered highly useful resources in enhancing soil fertility and also in build-up of soil organic matter. Organic matter decomposition provides plant nutrients in soil, which in turn increases crop productivity. Availability of nutrients and nitrogen (N) and phosphorus from organic waste materials is dependent upon the nature of organic residues, climatic conditions, and soil moisture activity. Keeping these factors in view, the present investigation was undertaken to study the transformation of N from different organic waste materials in two contrasting soils from an eastern India, subtropical region. The results showed that the amounts of ammoniacal-N ($\text{NH}_4\text{-N}$), nitrate-N ($\text{NO}_3\text{-N}$), hydrolysable N (HL-N), and nonhydrolysable (NHL-N) were increased for up to 60 days of soil submergence and increased further with the increase (1% by weight of soil) of organic residue application.

Considering the effect of various organic waste materials, it was found that the amounts of $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, HL-N, and NHL-N were higher with the application of groundnut hull as compared to wheat straw and potato skin, which may be due to relatively narrow carbon:N ratio of groundnut (22:43) than that of wheat straw (62:84) and potato skin (71:32); however, the results showed that the release of $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, HL-N, and NHL-N was in the order of groundnut hull > wheat straw > potato skin.

KEY WORDS: ammoniacal nitrogen, hydrolysable nitrogen, nitrate nitrogen, nonhydrolysable nitrogen, organic waste materials, submerged soil, transformation

DOMAIN: waste management policy

INTRODUCTION

Different types of organic waste materials, like crop residues or rural and urban wastes, are useful in augmenting soil fertility and increasing crop productivity. Most of the Indian subtropical soils are deficient in organic carbon (C) as well as nitrogen (N). Application of these organic waste materials in soils, therefore, helps the building up of plant nutrient status, especially N; however, such build-up of soil fertility status depends upon the nature of waste materials added and the dynamics of mineralisation immobilisation of nutrients (N, phosphorus [P], and sulphur[S]) in soils being mediated by soil microorganisms[1,2,3].

The status of organic N fractions in soils can be determined by hydrolysing the soil with 6N HCl[4]. Bremner[5] reported that more than 95% of the total N was in organic combination, a portion of which, on hydrolysis, is liberated as ammonium (10 to 25%), a greater portion as amino acids (25 to 40%), and a smaller fraction (1 to 5%) as amino sugars. These hydrolysable N (HL-N) fractions are the main source of the availability of N for the nutrition of organisms in the soil[6]. Dhillon et al.[7] reported that the total N, HL-N, and nonhydrolysable N (NHL-N) correlated significantly with the yield and N uptake by rice. Considering some of these factors, the present study was undertaken with an objective to investigate the influence of different organic materials on the transformation of N in soils of the Indian subtropics.

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MATERIALS AND METHODS

The surface (0- to 15-cm depth) soil samples from Mohitnagar (Inceptisol) and Bolpur (Alfisol) in the districts of Jalpaiguri and Birbhum, respectively, were collected. Then soils were crushed and sieved through a 20-mesh sieve. The relevant physicochemical properties of soils viz. pH, EC, organic C, cation exchange capacity (CEC), and available N (Table 1) were determined following the method described by Jackson[8]. In the present investigation, potato skin, groundnut hull, and wheat straw were used as organic wastes, and these organic wastes were dried, ground, and analysed for total C and N (Table 2). The levels of all three organic waste materials used at 0.5 and 1.0% by weight of the soil. The experiment was conducted in a laboratory at room temperature ($25 \pm 2^\circ\text{C}$) with seven treatments and three replications in a randomised block design. The seven treatments were T_1 = control (no application of organic waste materials); T_2 and T_3 = application of potato skin at 0.5 and 1.0% by weight of the soil, respectively; T_4 and T_5 = application of wheat straw at 0.5 and 1.0% by weight of the soil, respectively; and T_6 and T_7 = application of groundnut hull at 0.5 and 1.0% by weight of the soil, respectively. All the soils receiving the above seven treatments were kept submerged in standing water 5 + 0.5 cm above the soil surface, simulating lowland rice conditions. Soils from all three replications were analysed at 15-, 30-, 45-, and 60-day intervals after the treatment for different fractions of N.

RESULTS AND DISCUSSION

Ammoniacal Nitrogen ($\text{NH}_4\text{-N}$)

The results (Table 3) show that the amount of $\text{NH}_4\text{-N}$ increased with the period of submergence; however, the magnitude of such increase varied with the type of soil as well as applied organic waste materials. Comparing the result of different organic waste materials in both the soils, it was observed that the amount released with respect to $\text{NH}_4\text{-N}$ was highest in the T_6 and T_7 treatments, ranging between 60.2 and 88.1 mg kg^{-1} at 60 days of submergence. These amounts of release of $\text{NH}_4\text{-N}$ in groundnut were twice as high as was observed in potato skin and wheat straw treatments. The order of $\text{NH}_4\text{-N}$ release from these materials was groundnut hull > wheat straw > potato skin. The lower rate of $\text{NH}_4\text{-N}$ release from potato skin and wheat straw treatments can be attributed to narrower C:N ratios of these additives (Table 2), which limits mineralisation of N[9]. The percent increase of $\text{NH}_4\text{-N}$ in both the soils over the control progressively increased up to 60 days of submergence in all organic waste materials and was highest in the case of alfisol treated with 1.0% groundnut hull.

Nitrate-Nitrogen ($\text{NO}_3\text{-N}$) Content

The results (Table 4) show that the amount of $\text{NO}_3\text{-N}$ content in both soils gradually increased mineralisation of organic waste

TABLE 1
Physicochemical Properties of the Soil Used for the Experiment

Physicochemical Properties	Inceptisol (Mohitnagar Soil)	Alfisol (Bolpur Soil)
pH	6.02	5.70
EC (dsm^{-1})	0.17	0.49
Organic C (%)	0.92	0.58
CEC [$\text{Cmol}(\text{p}^+)\text{kg}^{-1}$]	23.70	7.86
Available $\text{NO}_3\text{-N}$ (mg kg^{-1})	1.52	0.87
Available $\text{NH}_4\text{-N}$ (mg kg^{-1})	8.34	7.50
Available P (mg kg^{-1})	10.38	8.20

TABLE 2
Results of Chemical Analysis of the Organic Residues Used for the Experiment

Chemical Properties	Potato Skin	Wheat Straw	Groundnut Hull
Total C (%)	48.50	38.96	35.45
Total P (%)	0.38	0.60	0.44
Total N (%)	0.68	0.62	1.58
C:N ratio	71.32	62.84	22.43
C:P ratio	127.63	64.93	80.56

TABLE 3
Effect of Potato Skin, Wheat Straw, and Groundnut Hull
on the Availability of NH₄-N (mg kg⁻¹ soil) in Inceptisol and Alfisol

Inceptisol (Mohitnagar Soil)									
Period of Submergence (days)									
Treatments	15		30		45		60		Mean
	% Increase Over Control		% Increase Over Control		% Increase Over Control		% Increase Over Control		
T ₁	9.2	—	10.5	—	12.5	—	14.6	—	11.7
T ₂	11.8	26.0	14.0	35.7	15.4	28.7	17.5	28.9	14.7
T ₃	14.8	55.8	17.5	70.0	19.5	69.9	20.7	61.0	18.1
T ₄	14.1	48.7	16.8	63.0	18.9	64.4	20.3	56.8	17.5
T ₅	19.4	102.0	25.8	153.4	27.4	148.5	29.6	147.5	25.5
T ₆	42.1	328.3	48.2	377.4	52.4	399.4	60.2	456.2	50.7
T ₇	55.2	45.9	65.7	52.0	72.8	602.9	78.4	647.5	68.0
Mean	23.8		28.4		31.3		34.5		
C.D. (5%)	0.2		0.2		1.3		0.8		

Alfisol (Bolpur)									
T ₁	8.1	—	9.2	—	11.2	—	12.6	—	10.3
T ₂	8.7	6.3	9.8	6.5	12.3	10.3	14.0	14.8	11.2
T ₃	9.8	17.1	11.5	20.5	13.9	27.0	16.7	41.7	12.9
T ₄	12.5	44.5	16.2	68.7	18.1	68.7	21.6	90.2	17.1
T ₅	18.8	107.0	29.9	207.2	32.1	208.3	34.1	215.7	28.7
T ₆	43.4	353.0	51.7	425.7	68.3	571.0	83.2	706.0	61.6
T ₇	50.7	426.4	57.3	481.2	73.4	621.7	88.1	755.7	67.4
Mean	21.7		26.5		32.8		38.6		
C.D. (5%)	0.3		0.2		0.2		0.8		

materials with time. The increase in the NO₃-N value was much lower as compared to the increase in the amount of NH₄-N in both soils. The results further revealed that the release of NO₃-N content in both soils showed a similar pattern to that of NH₄-N content. A slow increase in NO₃-N content in soils with the period of flooding might be the result of constant release of inorganic N from the slow mineralisation of organic resource materials as well as relatively greater thickness of the oxidised soil layer. As a result, it is possible that a higher rate of biological oxidation of NH₄-N results in a greater NO₃-N content in the oxidised soil layer with the simultaneous decrease in diffusion of NO₃-N to the anaerobic, reduced soil layer. Although NH₄-N is stable in the reduced zone of the soil, basal application of organic waste materials is usually placed deep enough to avoid immediate nitrification; however, diffusion of NH₄-N from the reduced zone to the oxidised zone



cannot be prevented[10]. Beri et al.[11] observed that the use of amendment in the soil with *Sesbania aculeata* resulted in the formation of NO₃-N under both field-capacity and saturated-soil conditions. In the case of both inceptisol and alfisol, with up to 60 days of submergence with the application of groundnut hull, wheat straw, and potato skin at 1.0%, the percent increase of NO₃-N over control was 174.2, 83.9, and 28.2 (inceptisol), and 118.8, 55.7, and 35.0 (alfisol), for each application, respectively.

HL-N and NHL-N

The results (Table 5) revealed that the amount of HL-N and NHL-N initially increased significantly; thereafter, the amounts decreased with the progress of submergence irrespective of treatments. The magnitude of such changes, however, varied with treatments and was highest in the treatment with groundnut hull at its highest level (1.0% by weight of soil). This result may be because the organic N of groundnut hull has a relatively low C:N

TABLE 4
Effect of Potato Skin, Wheat Straw, and Groundnut Hull
on the Availability of NO₃-N (mg kg⁻¹ soil) in Inceptisol and Alfisol

Inceptisol (Mohitnagar Soil)										
Period of Submergence (days)										
Treatments	15		30		45		60		Mean	
	% Increase Over Control		% Increase Over Control		% Increase Over Control		% Increase Over Control			
T ₁	2.1	—	2.7	—	3.5	—	4.2	—	3.1	
T ₂	2.6	5.4	3.2	4.5	4.2	7.7	5.5	13.2	3.9	
T ₃	3.4	13.9	4.2	14.3	5.8	23.2	7.0	28.2	5.1	
T ₄	3.6	15.2	4.2	14.8	6.3	27.8	8.7	45.0	5.1	
T ₅	7.7	56.2	11.1	83.8	11.9	84.7	12.6	83.9	5.7	
T ₆	11.9	98.5	14.7	119.5	17.4	139.5	19.6	154.0	10.8	
T ₇	13.7	116.0	16.7	139.6	19.6	161.3	21.6	174.2	18.0	
Mean	6.4		8.1		9.8		11.3			
C.D. (5%)	0.3		0.1		0.2		0.2			
Alfisol (Bolpur)										
T ₁	1.4	—	2.2	—	3.4	—	4.8	—	3.0	
T ₂	1.7	2.5	2.5	2.7	4.2	8.8	6.3	14.7	3.7	
T ₃	2.4	9.6	3.2	9.6	5.4	20.6	8.3	35.0	4.8	
T ₄	3.5	20.2	4.2	20.2	6.2	28.1	7.6	58.0	5.4	
T ₅	4.8	33.7	6.3	40.8	9.0	56.5	10.4	55.7	7.6	
T ₆	5.8	43.8	7.1	49.5	11.1	77.5	13.3	8.00	9.3	
T ₇	9.8	83.3	13.3	110.8	15.3	109.6	16.7	118.8	13.8	
Mean	4.2		5.5		7.8		9.6			
C.D. (5%)	0.2		0.2		0.2		0.3			

ratio and is converted to HL-N very easily as compared to other sources of organic materials[12]. Tusneem and Patrick[13] reported that the amount of total HL-N and NHL-N was found to be increased following the application of N-fertiliser. The N from organic sources is converted to HL-N because of microbial decomposition, which varies with the kind of C sources added to the soil. The progressive decline in HL-N content at the later period of submergence may be because of its continuous hydrolysis to amino acids and their subsequent mineralisation to ammonium and nitrate forms[14]. The results further indicate that the magnitude of decrease in the amount of NHL-N was relatively low compared to the HL-N fraction, which may be because of immobilised of mineralised N to nonhydrolysable organic nitrogen fraction[15].

A comparison of the results of different organic treatments revealed that the amounts of both HL-N and NHL-N in both the soils were higher in groundnut hull treatments, closely followed by wheat straw, possibly because of variation in the kinds of organic materials as well as the C:N ratio determining the process of mineralisation of organic resource materials.

CONCLUSION

From the present investigation it may be concluded that organic agricultural waste materials are very beneficial not only for maintaining soil fertility—particularly in respect to augmenting N content in soils—but also a source of C, which may improve soil physical conditions.

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TABLE 5
Influence of Organic Waste Materials on the Changes of
HL-N and NHL-N (mg kg⁻¹ soil) in Inceptisol and Alfisol

Inceptisol (Mohitnagar Soil)								
Period of Submergence (days)								
Treatments	15		30		45		60	
	HL-N	NHL-N	HL-N	NHL-N	HL-N	NHL-N	HL-N	NHL-N
T ₁	553.2	186.5	508.4	169.7	485.5	137.2	441.4	100.83
T ₂	643.1	211.4	630.3	192.9	589.8	152.3	503.6	117.8
T ₃	667.4	242.6	644.4	208.8	602.4	167.5	561.3	141.1
T ₄	725.4	221.5	698.9	198.8	621.2	156.5	579.8	130.0
T ₅	785.7	278.4	718.6	225.9	669.8	176.8	604.9	140.70
T ₆	807.2	268.6	714.9	215.7	658.8	171.4	617.9	134.7
T ₇	825.7	284.7	779.9	245.7	694.9	203.4	642.7	151.9
C.D. (5%)	204.7	18.4	27.7	16.9	22.4	13.8	17.3	12.9
Alfisol (Bolpur)								
T ₁	481.9	138.7	403.3	118.6	387.4	100.4	300.9	89.7
T ₂	502.4	149.1	431.9	130.7	412.4	106.8	381.7	94.7
T ₃	529.0	158.4	502.7	139.9	473.4	119.41	404.5	101.7
T ₄	539.4	154.5	509.2	141.4	419.8	110.2	389.4	99.1
T ₅	585.4	171.9	532.5	158.4	488.5	126.8	428.9	114.6
T ₆	558.7	161.7	515.7	149.3	451.7	113.5	417.4	103.4
T ₇	591.7	185.7	536.8	164.7	498.4	144.7	442.6	131.7
C.D. (5%)	12.7	9.8	9.3	10.1	16.7	8.3	12.7	9.9

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BIOSKETCH

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