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Full Length Research Paper

Mineralization of nitrogen from ^{15}N labeled crop residues at varying temperature and clay content

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A laboratory incubation experiment was carried out for 85 days to monitor the N mineralization during the decomposition of ^{15}N labeled wheat and rice straws incorporated at 5 g kg^{-1} soil at varying temperatures and with soils of varying clay content. Results have shown that N mineralization surpass immobilization 40th day onwards. Irrespective of temperature and clay content, mineralization of rice residue N was found to be significantly higher than that of wheat residue throughout the incubation period. Increasing temperature and clay content both had positive effect on residue N mineralization. At 85th day after incubation N mineralization from the residues was found to be 13 - 14%. Clay content, temperature, composition of the residues are important factors controlling plant residues decomposition under laboratory conditions.

Key words: Rice and wheat residues, straw, N-mineralization, immobilization.

INTRODUCTION

Rising costs of chemical fertilizers, as well as their possible long term adverse effects on soil health, crop productivity and environmental pollution have resulted to more attention on the recycling of organic wastes. Incorporation of organic materials through crop residues may be an important choice for maintaining or increasing soil fertility as it is well recognized that the organic matter is a key attribute of soil fertility. Crop residues have a great potential in India particularly in predominantly rice, wheat and sugarcane growing areas. The traditional practice of burning eliminates 70 to 80% of the N held in the crop residue (Sarkar et al., 2000). Consequently, the change from burning to straw incorporation will likely facilitate the cycling of N in residues back to the soil. Crop residues undergo mineralization before N becomes available to crops. Availability of crop residue nitrogen to succeeding crops is determined by the outcome of mineralization-immobilization processes (Paul and Juma, 1981; Jansson and Persson, 1982). Powlson et al. (1995) stated that net immobilization of soil nitrogen generally occurs when residues have a high C: N (>25:1). Soil temperature and texture as well as composition of straws are believed to exert a significant influence on N mineralization-immobilization dynamics of organic residues either through changing soil biota, enzymatic activities or through adsorption of soil organics (Singh et al., 1991). Except few works (Patil and Sarkar, 1993), not much information is available regarding the effect of crop residues incorporation on N dynamics at varying soil temperature and texture.

Therefore, the present laboratory study for 85 days was carried out to generate comprehensive informations regarding the effects of soil incorporation of rice and wheat straws on the dynamics of residue N mineralization-immobilization at varying temperatures and clay content, and to examine the residue inorganic N content in terms of NH_4^+ and NO_3^- at various intervals after incubation. ^{15}N stable isotope methodology was used to follow the turnover of labeled crop residue N in the inorganic pools.

MATERIALS AND METHODS

Laboratory experiment using soil with varying clay content and temperature was carried out for 85 days at the Division of Soil Science and Agricultural Chemistry, IARI, New Delhi, India. Labeled crop residues (rice and wheat straws) obtained from a previous greenhouse experiment using 20% atom excess urea were used.

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Table 1. Effect of types and levels of crop residues on inorganic nitrogen (NH_4^+ + NO_3^-) content mg kg^{-1} at different days of incubation.

Crop residue (C)	Days of incubation (D)						Mean
	0	10	20	40	60	85	
Control	19.1	21.1	23.4	25.5	26.8	27.1	24.8
Wheat	19.1	8.5	10.9	26.9	30.4	32.0	21.7
Rice	19.1	8.8	13.6	28.6	30.9	31.5	22.6

Sources: CD at (P = 0.05); C = 0.60. Data represented in this table are the mean values averaged over three clay contents and two temperatures.

Table 2. Effect of clay content of soil on inorganic nitrogen (NH_4^+ + NO_3^-) content mg kg^{-1} at different days of incubation.

Soil of varying clay content (S)	Days of incubation (D)					Mean
	10	20	40	60	85	
S_0	14.8	17.7	29.7	32.1	33.8	25.7
S_1	13.4	16.5	29.1	31.1	31.5	23.3
S_2	11.6	14.3	22.9	25.4	26.1	20.1

Sources: CD at (P = 0.05); S = 0.60. S_0, S_1, S_2 refer to original soil, 75% original soil + 25% sand and 50% original soil + 50% sand respectively and data represented in this table are averaged over three residue levels and two temperatures.

Table 3. Effect of temperature and days of incubation on inorganic nitrogen (NH_4^+ + NO_3^-) mg kg^{-1} content of soil.

Temperature (T)	Days of incubation (D)						Mean
	0	10	20	40	60	85	
T_1	19.1	12.5	16.1	26.7	28.9	29.8	22.7
T_2	19.1	13.2	15.8	27.3	29.8	30.6	23.4

Sources: CD at (P = 0.05); S = 0.49. T_1, T_2 refer to 20 and 35°C, respectively and data represented in this table are averaged over all three residue and clay contents levels.

The initial C:N ratios of rice and wheat straws were 82.9:1 and 89.5:1, respectively. The bulk surface soil (0 - 15 cm) of loamy texture belonging to Typic Haplustept (Inceptisol) collected from the Institute Farm had the following characteristics; clay 17.7%; pH 8.3, organic C 3800 mg kg^{-1}, total N 680 mg kg^{-1}, NH_4^+- N 10.2 mg kg^{-1}, NO_3^--N 15.3 mg kg^{-1}, field capacity (% moisture at 1/3 bar) 18.20. To get the soil with different clay contents (17.7, 13.3 and 8.85%), it was sieved (2 mm) and proportionately mixed with previously washed Jamuna sand at 0, 25 and 50%, respectively. Sterilized (autoclaved) white plastic pots were filled with 1 kg of these soils. Crop residues (viz., no straw, wheat straw and rice straw) were chopped to 2 mm pieces and mixed at 5 g kg^{-1} soil to the respective pots. Two sets of pots were placed in the rack of respective BOD incubators at a constant temperature of 20 and 35°C. Moisture content of the pots was maintained at field capacity (FC) throughout the incubation period by measuring the difference in weight loss. Soil samples were collected at 10, 20, 40, 60 and 85 days after incorporation of crop residues and analyzed for NH_4^+-N, NO_3^--N and ^{15}N. NH_4^+-N and NO_3^- -N were determined by steam distillation using the procedure described by Bremner and Edward (1965) and Bremner and Keeney (1966), respectively. Subsequently the titrated distillate was evaporated at 45°C for ^{15}N:^{14}N ratio analysis using Duma's method (Keeny and Nelson, 1982). The experiment was conducted in a factorial randomized complete block with 3 replications and statistical analysis of the data was performed applying SPSS software package and LSD was used for treatment means comparison as per the methods suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Incorporation of wheat and rice residue significantly reduced the inorganic N content from 19.1 mg kg^{-1} under unamended soil to 8.5 and 8.8 mg kg^{-1} soil for wheat and rice residue treated soils respectively within 10 days of incubation. From 10th to 20th day, no net N mineralization was observed but inorganic N level increased significantly from 40th to 85th day over control (Table 1). Higher clay content and temperatures have shown more inorganic nitrogen level and irrespective of levels of clay content and temperatures, inorganic nitrogen increased significantly from 10 days onwards throughout the incubation period (Tables 2 and 3). Maximum mean inorganic N content for wheat and rice residue treatments were recorded as 32.0 and 31.5 mg kg^{-1} respectively at 85^{th} day. But the value was found statistically at par

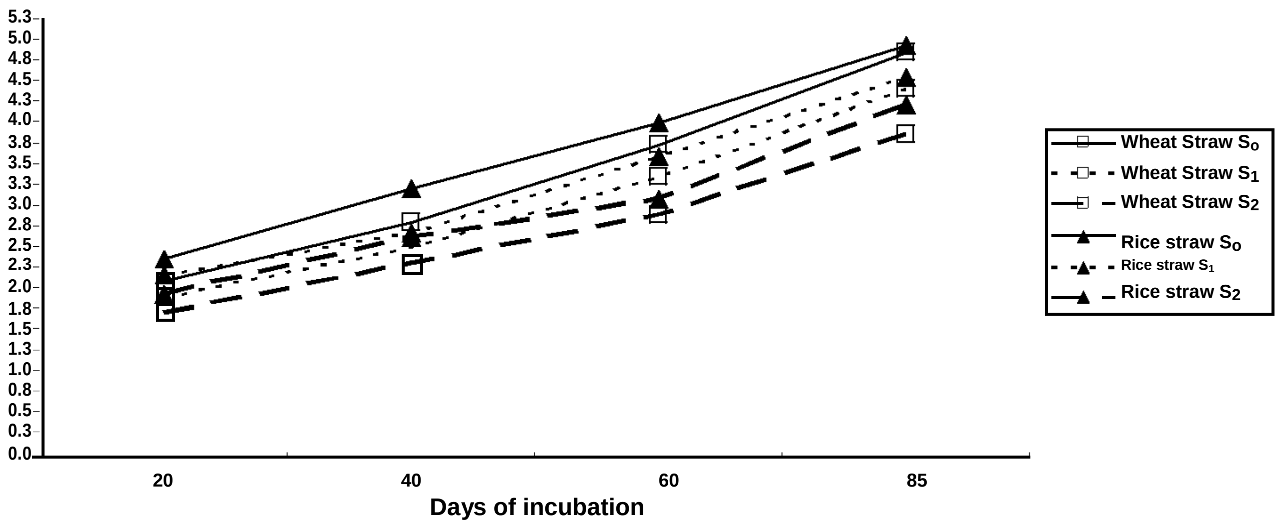

Figure 1. Mineralization of Nitrogen from ^{15}N labeled crop residues under varying clay content. S_0, S_1, S_2 refer to original soil, 75% original soil + 25% sand and 50% original soil + 50% sand respectively.

par for the residue treatments. However, rice residue treatment exhibited significantly higher level of mean inorganic N content than wheat residue treat-ment during 20th and 40th day (Table 1). Increasing the temperature from 20 to 35°C increased inorganic N content from 12.5 to 13.2 mg kg^{-1} at 10th day, 26.7 to 27.3 mg kg^{-1} at 40th day, and 29.8 to 30.6 mg kg^{-1} at 85th day of incubation (Table 3). N-immobilization in terms of NH_4^+- N + NO_3- N estimated over control following straw incorporation was found to be prominent up to 20th day, thereafter no net mineralization was found up to 40th day. However, after 40th day, N mineralization exceeds that of immobilization ranging from 14 - 17% at 60th day and 19 - 20% at 85th day as estimated over control that is, by the difference method (Table 1). Wagger et al. (1985) demonstrated mineralization of N from ^{15}N labeled wheat and sorghum residue to be 12.5 - 14.7% and 14.9 - 32.9% respectively during one crop season. More or less similar results were also reported by Sarmah and Bordoloi (1994) who found conspicuous net immo-bilization of N up to 4 weeks in soils due to treatment with wheat straw after which mineralization exceeded immo-bilization. However, Christensen (1985) observed net immobilization just after wheat and barley straw burial in a coarse and sandy loam soil under field condition reaching maximum after six months. This may be due to the fact that mineralization rates in field soils used to be lower than those reported in controlled environment since conditions are not continuously favourable for biological activity in natural ecosystems. Higher clay content in the original soil as compared to sand mixed soils caused more retention of inorganic N either due to the presence of more aerobic microsites followed by less loss through denitrification or more stabilization of the microbes by the formation of the so-called ‘clay envelop’ which becomes effective against predation (Marshall, 1975). Positive effect of clay on mineralization has been found by Campbell and Sauster (1982). However, negative effects were also reported by Van Veen et al. (1985) and Amato et al. (1987). Increasing the temperature from 20 to 35°C resulted in higher inorganic N content in the incubated soil irrespective of residues or clay content. N mineralization is a temperature dependent microbial process with optimum temperature being 35°C (Poovarodam and Tatelll, 1988) or 30 to 35°C (Cassman and Munns, 1980).

The rate of mineralization of N from labelled crop residues in soil was considerably higher at higher clay content and higher temperature (Figures 1 and 2). Per cent inorganic N recovered in soil from labeled wheat and rice residues were 5.69 and 6.47% at 20th day, 7.61 and 8.53% at 40th day and 10.03 and 10.76% at 60th day and 13.22 and 13.81% at 85th day after incubation, respectively (Table 4). Significant decrease in mean inorganic N derived from crop residues was recorded for decreasing clay content. Moreover, temperature had positive effect on residue mineralization showing higher mean inorganic N (8.97%) at 35 than 20°C (7.39%). At 85th day of incubation per cent inorganic N recovered in soil from labeled wheat and rice residue was 13.22 and 13.81%, respectively (Table 4). Comparatively higher value (19 - 20%) obtained from difference method (Table 1) may be due to the enhancement of soil organic N mineralization on incorporation of crop residues. The present data are in agreement with the findings of Amato et al. (1987). Similarly Wagger et al. (1985) demonstrated mineralization of N from ^{15}N labeled wheat and sorghum residues to be 12.5 - 14.7% and 14.9 - 32.9%, respectively during one crop season. Mineralization of rice residue was found to be significantly higher than the wheat residue. This phenomenon may be due to higher

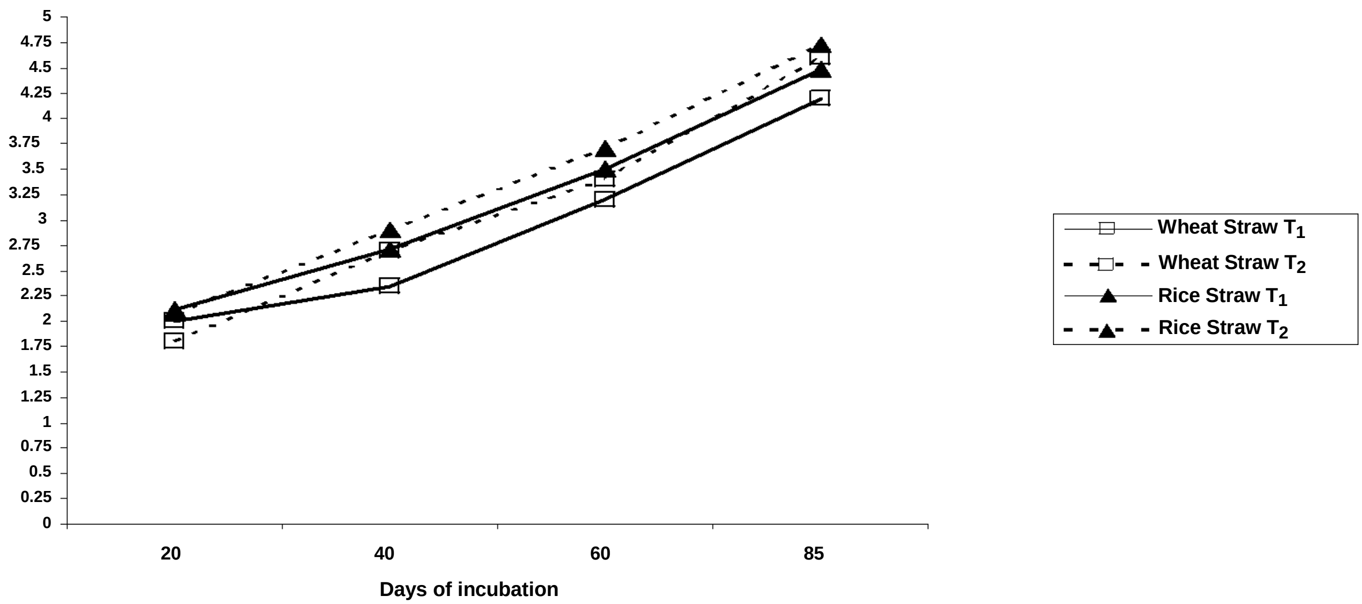

Figure 2. Mineralization of nitrogen from ^{15}N labeled crop residues under varying temperatures. T_1 and T_2 refer to 20 and 35°C, respectively.

Table 4. Per cent inorganic N (NH_4^+ + NO_3^-) recovered in soil from ^{15}N labeled crop residues under varying temperatures and clay content of soils at different days of incubation.

Crop residues	Soil of varying clay content	Days of incubation (D)							
		20		40		60		85	
		T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
Wheat	S_0	6.32	6.28	8.13	8.65	10.99	11.52	14.45	14.81
	S_1	5.64	5.82	7.32	7.76	9.98	10.25	13.08	13.67
	S_2	5.01	5.16	6.64	7.21	8.56	8.84	11.24	12.01
	Mean	5.69		7.61		10.03		13.22	
Rice	S_0	7.01	7.22	9.14	10.19	11.56	12.62	14.02	15.85
	S_1	6.11	6.92	7.65	8.47	10.29	11.44	13.34	14.15
	S_2	5.69	5.92	7.81	7.95	8.94	9.71	11.55	13.95
	Mean	6.47		8.53		10.76		13.81	
Sources		CD at (P = 0.05)							
C		0.30							
S		0.37							
T		0.30							

NB : S_0, S_1, S_2 refer to original soil, 75% original soil + 25% sand and 50% original soil + 50% sand respectively and T_1, T_2 refer to 20^0C and 35^0C, respectively

lignin content of wheat residue over rice residue as the C:N ratio was more or less similar for both the residues. The nature and content of lignin is a good index for prediction of net N release (Berg and McClaughterty, 1987). In a study with several parameters Muller et al. (1988) concluded that lignin content was better than N concentration or C:N ratio in predicting the amount of mineralized N. Increasing temperature from 20 to 35°C increased the per cent inorganic N derived from residue. This may be due to higher degree of mineralization at higher temperature. Similarly increasing clay content also showed positive effect on residue N mineralization. These findings are in agreement with the observations of Patil and Sarkar (1993). Higher temperatures and soil clay content led to best N mineralization from residues in the present study as evidenced from the Table 4. Thus, it can be concluded that amount of clay in soil, temperature and residue type play an important role in modifying the mineralization and immobilization pattern of crop residue nitrogen. Therefore, nature of soil, temperature, residue type and period of incorporation should be assessed to get maximum benefit of available N pools during straw decomposition.

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