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Nitrogen Mineralization of Cereal Straws and Vetch in Paddy Soil by Test Tube Analysis

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ABSTRACT

Mineralization of organic N is an important factor in determining the appropriate rate of organic matter application to paddy fields. A kinetic analysis was conducted for nitrogen mineralization of rice, barley, Chinese milk 0vetch (*Astragalus sinicus* L.; MV) and narrow leaf vetch straw in paddy soil. Nitrogen immobilization occurred rapidly and its rate increased in straw with high C/N ratio. The amount of nitrogen mineralization was rapid in the first year of rice-vetch cropping system. The rate constant (K) depended on the C/N ratio of organic matter. Mineralization of straw increased at high temperature. The amount of available N increment resulted in fast mineralization of straw, especially in rice and barley straw. Chinese milk vetch had the greatest mineralization rate at all temperatures and fertilization levels followed by narrow-leaf vetch. However, rice and barley straws with high C/N ratio immobilized the soil N at the initial incubation duration. Chinese milk vetch or narrow leaf vetch was not effectively mineralized in mixed treatments with rice or barley straw. The mineralization rate of organic matter was mostly affected by the C/N ratio of straw and temperature of incubation. Organic matter with low C/N ratio should be recommended to avoid the immobilization of soil N and the increasing mineralization rate of straw.

Keywords : paddy soil, organic matter, nitrogen mineralization, incubation, kinetic analysis.

When evaluating the nitrogen from soil organic matter during the period of rice growth, the pattern of mineralization of the soil organic nitrogen in the same period is as important as the total amount released. The prediction of the time of nitrogen release is particularly important as it is closely related to the timing of the fertilizer application.

Nitrogen supply potentials of soil have been evaluated with the incubation method in which the effect of air-drying on ammonification or the effect of soil temperature has been of specific concern(Yoshino and Dei, 1974., Suzuki and Sawada, 1993). The incubation method, as reported by Harmsel et al (1955) is simple, rapid and cheap. However, it is very difficult to correlate the results with the actual field data because nitrogen release is merely measured in the short period of a week or two in the incubation test.

Hence, the results are meaningful only when relative nitrogen supply potentials are evaluated among different organic matters.

Mineralization rates of labelled and stabilized soil organic N from different crop residues decomposing in soil have been previously reported and were described with the first-order rate equation, $dN/dt = -K*N$, where N is the mineralizable organic N from crop residues and K is a constant (Matus and Rodriguez, 1994). Contrary to Ruiter's result (1993), Rubaduka et al (1991) introduced that amounts of mineralized N were influenced by soil types due to differences in drainage and aeration. The relative comparison between *L. diversifolia* and *S. sesbania* was not influenced by differences in soil organic matter or soil, pH but soil texture.

We examined the process of soil nitrogen release. A concept of effective temperature was introduced in our studies. It was well known that the aerobically incubated soil accumulated less ammonium nitrogen than the anaerobically incubated soil. The difference between them was the greatest at lower temperatures.

In this study, the laboratory incubation method was used to compare N mineralization potentials of several types of straw in paddy soil. The objective of this study was to investigate the mineralization speed and type by straw sources, temperatures, and N levels.

MATERIALS AND METHODS

In order to evaluate the mineralization of the soil organic nitrogen, paddy soil samples (15g) were kept in test tubes. Samples in the stoppered test tubes were incubated at three temperature levels 20, 25, and 30℃, respectively. The amount of released ammonium nitrogen was determined. The test tube size was 22 mm inner diameter and 100 mm depth. Soil samples were mixed with 10 ml distilled water stirred thoroughly, and incubated at the controlled temperature. Straw was milled and sieved with a 2 mm sieve.

After incubation, 50 ml 2M KCl was added and then filtered with Wattman filter paper No. 2. Ammonium nitrogen was analyzed by Indophenol method

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Table 1. Chemical properties of soil samples.

pH (1:5)	EC (1:5)	Av. P_2O_5 (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	OM (%)
5.7	0.21	55	8.9	0.82	1.91	1.7

Table 2. Chemical compositions of straws used or the kinetic analysis of mineralization of organic matters.

Compositions	Nitrogen	C/N ratio	P	K	S
Barley	0.36	121	0.36	2.34	0.57
Chinese milk vetch	2.12	15	0.30	1.47	0.38
Narrow leaf vetch	1.93	16	0.28	1.45	0.21
Rice	0.52	76	0.24	0.21	0.13

Table. 3. Equations for different reaction models.

Reaction model	Reaction equation
1) Simple type	$N=No^1 * (1-EXP(-K_1*T)) + A$
2) Simple and parallel	$N=No^1 * (1-EXP(-K_1*T)) + No^2 * (1-EXP(-K_2*T)) + A$
3) Organic and inorganic parallel	$N=No^1 (1-EXP(-K_1*T)) + N_{im}*(1-EXP(-K_{im}*T)) + No^2*(1-EXP(-K_2*T)) + A$

N : Accumulated inorganic nitrogen
No^1, No^2 : Decomposible organic nitrogen
N_{im} : Organic nitrogen
K : Number of reaction speed
T : Time

Table 4. Estimated parameters in the equations for nitrogen mineralization process based on Akaike's Information Criterion.

Straw	N (mg/soil 15g)	No^1	A (mg/15g)	K (day)	Ea (KJ/mol)	AIC	S
Control	0	10.4	2.2	0.034	68	59	30
	0.6	14.3	4.8	0.038	51	66	49
	1.2	17.1	11.9	0.021	117	86	185
Barley	0	13.0	0.3	0.031	39	63	38
	0.6	12.2	3.3	0.043	54	60	31
	1.2	22.1	7.7	0.023	69	80	123
Chinese milk vetch	0	36.6	1.9	0.037	97	93	285
	0.6	46.5	5.5	0.029	85	68	151
	1.2	45.7	7.2	0.058	20	91	249
Narrow leaf vetch	0	28.7	1.4	0.033	95	90	231
	0.6	38.2	4.6	0.037	76	99	425
	1.2	38.2	7.3	0.047	51	100	456
Rice	0	16.0	2.2	0.008	103	52	18
	0.6	20.2	6.1	0.007	137	75	88
	1.2	14.1	10.6	0.032	15	78	105
Rice + Chinese milk vetch 100	0	39.4	5.3	0.008	80	84	157
	0.6	29.9	5.1	0.040	91	95	327
	1.2	37.2	8.1	0.039	72	96	354
Rice + Narrow leaf vetch 100	0	36.1	2.3	0.012	104	87	198
	0.6	24.5	5.8	0.030	52	80	122
	1.2	22.8	11.0	0.029	81	91	260

N, amounts of mineralized nitrogen; No^1, N-mineralization potential;
A, Soluble organic N; K, mineralization rate constant (day^{-1}); Ea, apparent activation energy ($cal\ mol^{-1}$);
AIC, Akaike's Information Criterion, which is useful to compare with some models; S: Residual sum of squares.

using colorimeter at 1, 2, 4, 8, and 12 weeks after incubation.

RESULTS AND DISCUSSION

The release of ammonium nitrogen was apparently observed under the anaerobic condition even after 12-week incubation (Fig. 1). The greatest release of ammonium nitrogen was observed at the higher incubation temperature. On the contrary, the release of ammonium nitrogen the least in the rice and barley straw over all incubation periods.

Soil organic nitrogen mineralized faster at a higher incubation temperature; a rise in temperature of 10℃ increased the rate of mineralization two to four times (Sigurbjornsson, 1973, Toda. 1970).

The amount of ammonium nitrogen increased with the length of incubation period. It was also proportional to the temperature between 20 and 30℃. As reported in the Farooqui et al. (1983)'s study where the C/N ratio, 22, was the critical point for the net mineralization of organic nitrogen. Chinese milk vetch had the greatest mineralization rate (Fig. 1a, 1b, 1c) at over all temperature and fertilization levels, and was followed by narrow leaf vetch. It implies that the mineralization rate is greatest in low C/N ratio. However, rice and barley straw with high C/N ratio immobilizes the soil N at the initial incubation time. The mineralization rate of the organic matter was most greatly affected by the C/N ratio and temperature.

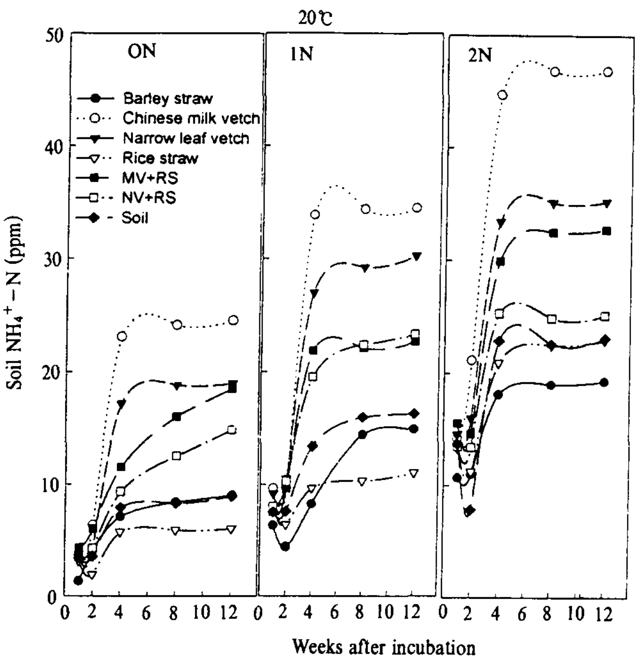

Fig. 1a. Nitrogen mineralization of oganic matters as affected by straw sources and applied N at 20℃ in test tube incubation test.

In order to calculate K and N, we had to give an adequate value to T which had already been estimated to be about 15℃ by regressing the curves in Fig. 1.

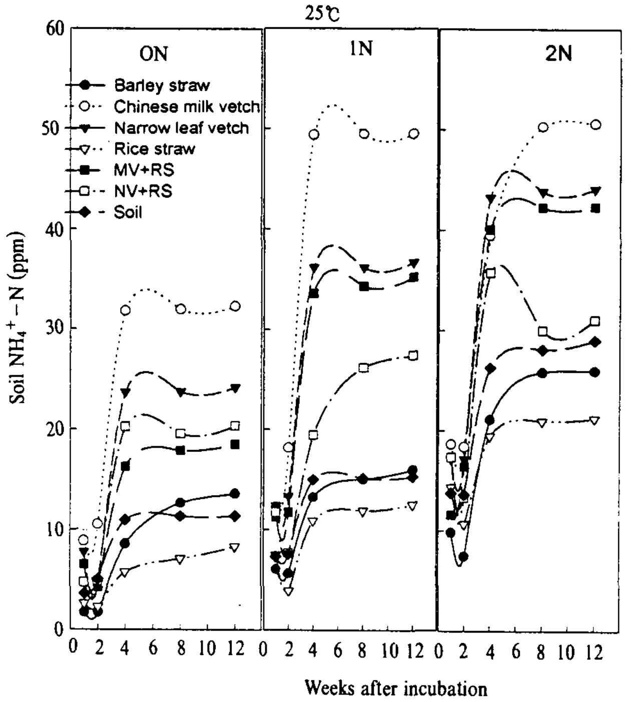

Fig. 1b. Nitrogen mineralization of oganic matters as affected by straw sources and applied N at 25℃ in test tube incubation test.

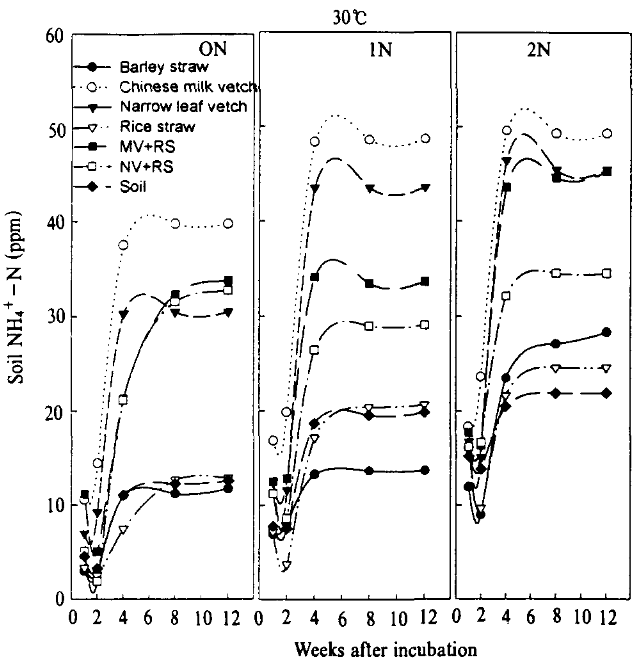

Fig. 1c. Nitrogen mineralization of oganic matters as affected by straw sources and applied N at 30℃ in test tube incubation test.

However, the best approximation was calculated by using the least square method from the data of ammonium nitrogen released over the different periods of incubation at temperatures between 20 and 30℃.

As for the relationship between the effective temperature and the ammonium nitrogen released in the submerged soils with different fertility levels, the equation(1) is useful for simplifying the relationship and evaluating the ammonification process of soil organic nitrogen.

By determining the ammonium release pattern at a certain temperature in the incubation test, we can predict the release pattern for ammonium nitrogen at different temperatures by using the equation.

The release of ammonium nitrogen was always high in the soils treated with the low C/N straw rather than the high C/N straw over all incubation periods. This result is similar to Ruiter et al. (1993). The contribution of the various organisms to N mineralization was different depending on sites and farming systems.

CONCLUSION

Over all, the effect of the temperature on the release of ammonium nitrogen in submerged soil was apparent. The equation proved to be applicable not only for the incubation test but for daily and seasonal variations of the temperatures in the field.

The nitrogen supply potentials of paddy fields in Korea seemed to be controlled by the soil temperature. Therefore, this concept of the effective temperature can provide a useful tool.

Organic sources are as important as incubation periods for N release. The different C/N ratios of various straw affected the N release from organic materials and soil. To avoid immobilization of applied and soil N, C/N ratio should be considered. If the organic matters have high C/N ratio, a large amount of N is needed to promote initial plant growth, but it may increase the volatilization due to the soil microorganisms in the initial plant growth stage (Cho and Choe, 1999).

Soil surface temperature and C/N ratio of mulching materials may affect the release of N. The higher temperature, the greater was the N mineralization. For faster N mineralization the N application time should be earlier and the quantity of fertilizers should be adjusted to the low C/N ratio in estimating the amount of nitrogen in rice and vetch cropping systems.

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