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Nitrogen Dynamics in Soils Following the Addition of ^{15}N-Labelled Rice Straw

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The transformation of rice straw-N and the native soil-N was investigated to make clear the nitrogen dynamics following the addition of ^{15}N-labelled rice straw to three soils. The results were summarized as follows :

1) The eventual mineralization rates of rice straw-N and soil-N during the period of 28 weeks' incubation ranged from 17 to 24% and from 1 to 2%, respectively.
2) The addition of rice straw resulted in the increase of the mineralization of soil-N due to priming effect which was valued 3-10 mg N/100 g dry soil. The magnitudes of the priming effect were significantly correlated with the mineralized amounts of rice straw-N.
3) The newly accumulated nitrogen derived from rice straw-N was more susceptible to mineralization than that of native soil-N through the air-drying effect.

INTRODUCTION

It is important to consider the recycling of plant nutrients by returning crop residues to the soil to maintain the soil fertility. The efficient use of crop residues can also decrease the need for a heavy application of chemical fertilizers, which might lead to the deterioration of the soil fertility and ecosystem (Honya, 1975).

In many countries, rice straw has been utilized in the form of compost, incorporated directly into the field, and returned to the field as ash after burning. In Japan, rice straw has been customarily returned to the field soil after being made into compost. This practice has been considered as having an important effect upon preserving the soil fertility of the paddy soil and the yield of rice. However, the return of rice straw as compost has been progressively decreasing due to the increasing application of chemical fertilizers, the change from draft animals to agricultural machinary and labor shortage of farms. Application of rice straw directly into paddy soil is a very useful and practical method which enables not only to maintain soil fertility but also to reduce the labor necessary to make and apply the compost (Broadbent, 1979).

Under such circumstances, it is very significant to obtain a better understanding of nitrogen dynamics associated with the decomposition of rice straw in soil. The present study was conducted to compare the mineralization rate of the added straw nitrogen with that of the native soil nitrogen, and to elucidate the priming and drying effects of rice straw application on the nitrogen dynamics of soil.

MATERIALS AND METHODS

Soil samples

The soils used were three paddy soils collected from their ploughed layers. The soils were ground and sieved through a 2 mm screen without air-drying. Some properties of the soil samples were given in Table 1.

Table 1. Some physico-chemical properties of soils used.

Soil	pH		Total N	Total C	C/N	CEC me/100g dry soil	Texture	Major clay mineral	MWHC*
	H_2O	N-KCl	mg/100g dry soil						
Kasuya	5.6	4.8	239.7	2411	10.1	15.8	CL	Metahalloysite	60.5
Nagano	6.1	5.1	138.3	1443	10.4	18.4	CL	Montmorillonite	60.2
Miyakonojo	6.3	5.7	368.6	5369	14.6	24.9		Allophane	116.3

* Maximum water holding capacity, g H_2O/100g dry soil.

^{15}N-labelled rice straw

Rice (*Oryza sativa* L., cv. Hoyoku) seeds were sterilized with 70 % ethanol and then 2 % calcium hypochloride, washed with tap water, and germinated on moist sand. The seedlings were grown under natural light at 30 °C in the growth chamber of phytotron. The composition of sand culture's medium was as follows : 4-20 ppm N as $(NH_4)_2SO_4$ with 29.34 % excess ^{15}N, 10 ppm P and 20 ppm K as KH_2PO_4 plus K_2HPO_4, 1 ppm Fe as Fe-EDTA, 40 ppm Ca as $CaCl_2 \cdot H_2O$ and 5 ppm Mg as $MgSO_4 \cdot 7H_2O$. The micronutrients were supplied with a small amount of tap water. The pH of nutrient solution was adjusted at 6.2. The rice was harvested at 60 days after germination, dried at 80 °C for 2 days and ground to 32 mesh size. The straw contained 37.00 % C and 1.875 % N with 23.90 % excess ^{15}N.

Incubation and determination

The three moist soils corresponding to 350 g dry soil *were* treated with 14 g of the ground rice straw labelled with ^{15}N. Each soil was contained in a polyethylene bag and the moisture was brought to 60 % of the maximum water holding capacity. The bags were closed and incubated at 30 °C for 28 weeks. The moisture lost by evaporation was made up frequently by adding the deionized water. Each treatment was run in duplicate. The "check soil" referred to the soil treated without the straw.

The drying effect on the mineralization of the tagged and native nitrogen in soil was measured by the following way : after 24 weeks' incubation a portion of samples was removed and dried at room temperature for 5 days, and then remoistened and reincubated for 4 weeks under the same conditions mentioned above. The corresponding controls were carried out. The accelerated mineralization of the nitrogen due to drying of soil, the so-called drying effect, was computed from the difference between the air-dried samples and the controls.

Mineral nitrogen released from straw and native soil organic matter during the decomposition was determined by Conway's microdiffusion method (Kai and Harada, 1973). ^{15}N concentration of the inorganic nitrogen was determined by emission spectrometry using a JASCO NIA-1 Type Analyzer, Japan Spectroscopic Company (Fielder and Proksch, 1975).

RESULTS AND DISCUSSION

Three soils were amended with 4 % ^{15}N-labelled rice straw. Mineralization of rice straw-N and native soil-N in the course of 28 weeks' incubation was shown in Table 2.

Table 2. Amounts of mineralized nitrogen at various time intervals, following the addition of ^{15}N-labelled rice straw to soils (Mineralized mg N/100 g dry soil).

Soil			Incubation period (weeks)								
			0	2	4	8	12	16	20	24	28
Kasuya											
	Amended	Rice Straw-N	0.1	3.8	8.2	14.9	15.4	16.1	15.5	15.3	14.6
		Soil -N	0.6	1.8	4.6	8.5	9.1	9.8	9.4	9.8	11.0
		Total -N	0.7	5.6	12.8	23.4	24.5	25.9	24.9	25.1	25.6
	Check	Soil -N	0.6	1.7	3.1	2.5	3.1	3.8	4.4	4.3	4.5
Nagano											
	Amended	Rice Straw-N	0.1	7.6	10.2	11.6	13.2	13.0	13.1	12.8	12.9
		Soil -N	1.1	3.0	3.9	5.0	5.4	5.5	5.5	5.7	5.5
		Total -N	1.2	10.6	14.1	16.6	18.6	18.5	18.6	18.5	18.4
	Check	Soil -N	1.1	1.8	2.6	2.8	2.7	2.4	2.7	2.9	2.5
Miyakonojo											
	Amended	Rice Straw-N	0.1	1.2	1.6	4.8	12.0	16.1	18.1	18.7	18.3
		Soil -N	0.9	1.0	1.1	3.6	8.7	11.9	13.4	13.4	13.9
		Total	1.0	2.2	2.7	8.4	20.7	28.0	31.5	32.1	32.2
	Check	Soil -N	0.9	2.6	4.0	4.0	4.2	3.6	4.1	4.2	3.6

Nitrogen of both straw and soil was rapidly mineralized in the first 12 weeks of incubation and reached stable levels in Kasuya and Nagano soils. On the other hand, the contrasting sigmoid pattern of nitrogen mineralization was observed in Miyakonojo soil. The mineralizations of both the sources in Miyakonojo soil were delayed in the first 4 weeks of incubation, thereafter progressively proceeded and showed to level off to a low rate after about 20 weeks of incubation. The mineralization rates of rice straw-N during 28 weeks' incubation in Kasuya, Nagano and Miyakonojo soils were 20, 17 and 24 %, and those of native soil-N were 5.3, 5.2 and 3.8 %, respectively. Thus, the eventual rates of nitrogen mineralization of both the sources did not greatly differ among the soils. The mineralization rates of soil-N in the check soils were 2.2, 2.3 and 1.0 %, respectively.

The differences in mineralization rates of native soil-N between the soils amended with straw and the check soils were the accelerated mineralization due to application of rice straw. This priming effect was given in Figure 1.

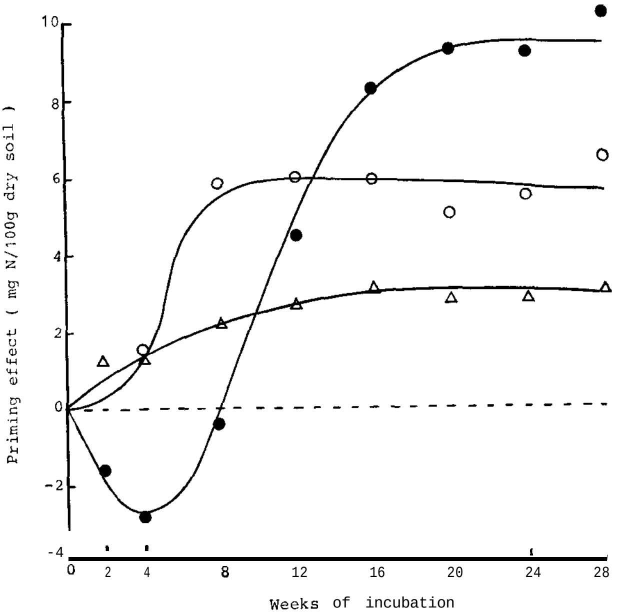

Fig. 1. Priming effect of ^{15}N-labelled rice straw application on mineralization of native soil organic nitrogen.
○ : Kasuya soil, △ : Nagano soil, ● : Miyakonojo soil.

The patterns of priming effect of three soils in the course of incubation were well resemble to those of mineralization of rice straw-N. In Miyakonojo soil, the priming effect was initially negative in the first 8 weeks' incubation through the immobilization of mineralized nitrogen of rice straw by the native soil organic matter. The priming effect was eventually larger in Miyakonojo soil and smaller in Nagano soil. This order was parallel with those of the total nitrogen contents of soils (Table 1). In addition, a positive correlation ($r=0.996$) was observed between the magnitudes of priming effect on mineralization of native soil-N following the addition of rice starw and the mineralized amounts of rice straw-N in soils. Masayna et al. (1985) reported the priming effect that the application of fertilizer nitrogen resulted in an increase of mineralization of native soil-N based on plant nitrogen uptake in greenhouse pots.

The nitrogen-supplying power of soil is often measured with the effect of drying on the mineralization of nitrogen (Kai *et al.*, 1973 ; Ahmad *et al.*, 1973 ; Kai *et al.*, 1984). Table 3 showed the drying effect on the mineralization of soil organic matter derived from native soil-N and rice straw-N after 24 weeks' incubation of three soils amended with ^{15}N-labelled rice straw. As shown in Table 3, the amounts of mineralized nitrogen due to the drying effect *were* **remarkably larger in the amended** Kasuya and Nagano soils than in their check

Table 3. Drying effect on mineralization of rice straw-N and soil-N in soils after 24 weeks' incubation. (mg N/100 g dry soil)

		Kasuya	Nagano	Miyakonojo
Amended soil	Rice straw-N	9.2 (15.4)	6.9 (11.1)	3.4 (6.0)
	Soil -N	6.4 (3.2)	4.1 (4.0)	4.3 (1.2)
	Total -N	15.6 (6.6)	11.0 (6.7)	7.7 (1.9)
Check soil	Soil -N	10.0 (4.9)	5.2 (5.0)	9.0 (2.5)

Figures in parentheses showed the percentage of remained organic nitrogen in each fraction after 24 weeks' incubation.

soils. Further a larger proportion of mineralized nitrogen was derived from the soil organic nitrogen originated from rice straw-N than that from the native soil-N. On the contrary, the drying effect of Miyakonojo soil amended with rice straw was somewhat diminished during the incubation.

These results indicated that the application of rice straw was effective to accumulate a decomposable organic nitrogen in soil and increase the nitrogen-supplying power of soil. This is not true for Miyakonojo soil ; the amended soil mineralized less nitrogen after drying and remoistening than the check soil. The reason is not known, but it may be a result of the high rate of mineralization of both rice straw-N and native soil-N due to the priming effect following the addition of rice straw. The reserves of decomposable nitrogen in the amended Miyakonojo soil may have been depleted during this period so that less nitrogen remained to be rendered decomposable through the air-drying effect than that in the check soil.

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