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IMMOBILIZATION, MINERALIZATION AND THE AVAILABILITY OF THE FERTILIZER NITROGEN DURING THE DECOMPOSITION OF THE ORGANIC MATTERS APPLIED TO THE SOIL

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KEY WORDS

Clayey red and yellow soil N transformation ^{15}N analysis Organic matters

SUMMARY

Immobilization and mineralization of the tracer nitrogen ($K^{15}NO_3$) applied to the soil together with several organic matters during their decomposition was investigated in incubation experiments.

After incubation for three months at 30°C, the decomposition rates of rice straw, hardwood bark, sawdust, softwood bark and peat moss were 41, 15, 7, 5, and 5%, respectively. After incubation for three months at 30°C, 100 and 80% of the fertilizer nitrogen were immobilized in the treatment with 2.0% of rice straw and sawdust carbon, respectively. These resulted in the lowered uptake of the fertilizer nitrogen by plants. In case of peat moss and barks, the amount of fertilizer nitrogen which transformed to the organic nitrogen fractions was quite small and the plant uptake of the nitrogen was hardly affected. Remineralization of the immobilized nitrogen was clearly observed after 2 months' incubation in case where rice straw carbon was added to the extent of 0.5 and 1.0%, but it was not observed in case where other organic matter carbon was added.

The data showed that peat moss and barks were highly resistant to the action of microorganisms. As a result, the immobilization process of the fertilizer nitrogen incubated with these organic matter was quite slow.

INTRODUCTION

It is well known that a portion of the fertilizer nitrogen is immobilized and this immobilized nitrogen is again mineralized during the decomposition process of the organic matter applied to the soil[1,6,7,8,11,12,13]. Amongst organic materials applied to the soil such as rice straw, bark, sawdust and excrement of livestock, are included fresh or undecomposed as well as well-decomposed ones. As a result, it seems that they differ in their decomposition rates after application to

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the soil, as well as in their effects on fertilization, and especially on the behavior of nitrogenous compounds. However, immobilization and mineralization of the nitrogen released from organic matter such as woody matter, as well as those of the fertilizer nitrogen, still remain to be solved.

In the present study, rice straw and peat moss were used as samples of herbaceous organic matter, while sawdust and bark as samples of woody organic matter. We investigated the process of their decomposition, and the behavior of fertilizer nitrogen and the availability of the fertilizer nitrogen during the organic matter decomposition, so as to clarify the characteristics of such undecomposed organic matter when applied to the soil.

MATERIALS AND METHODS

Experiment 1. The decomposition of organic matter: A clayey red and yellow soil containing 0.7% C and 0.06% N was used as a sample for the incubation tests. Organic materials (rice straw, peat moss, softwood-sawdust, softwood bark, and hardwood bark, having the C/N ratios of 56, 44, 268, 579, and 76, respectively) were applied at the rates of 0.5, 1.0, and 2.0 g of carbon per 100 g of soil, together with or without 20 mg of nitrate nitrogen. In addition, 4.5 mg of P, 28 mg of K, and 1.8 mg of Mg per 100 g of soil were applied. In addition, sufficient amount of $CaCO_3$ was added to keep the soil at pH 5.6–6.2. The moisture content was maintained at 60% of the maximum water holding capacity. The incubation was continued for 3 months at 30°C. CO_2 discharge during these treatments was periodically estimated by a titration method.

Experiment 2. Immobilization and mineralization of nitrogen in the soil: The treatment were made in the manner similar to those in Experiment 1, except for the use of $K^{15}NO_3$. After a fixed period of days, the soil samples incubated with the organic matter were divided into 4 fractions according to the Stewart's method[11], that is; (A) inorganic nitrogen fraction; (B) distillable acid-soluble nitrogen fraction; (C) nondistillable acid-soluble nitrogen fraction; and (D) acid-insoluble nitrogen fraction. Nitrogen contents in each fraction were estimated, and ^{15}N analysis was made by the use of emission spectrophotometry[9].

Experiment 3. The availability of fertilizer nitrogen by plants: Organic matter and $K^{15}NO_3$ were preincubated in the soil for 0, 45 and 90 days at 30°C as in the case of Experiment 2. After the preincubation, the soils were assayed by using Neubauer's method. Rye was grown as an indicator plant in the Neubauer's pot for 18 days and analyzed for the total N and ^{15}N by a semi-micro-kjeldahl procedure and by an emission spectrophotometry[9], respectively.

RESULTS AND DISCUSSION

Experiment 1. CO_2 discharge reached a peak in 1 or 2 days after incubation and it increased in proportion to the amount of organic matter (Figs. 1 and 2). Such rapid discharge of CO_2 was considered to be due to the decomposition of labile organic matter such as glucose. During a 3-month period, CO_2 has accumulated to the extent of 3000, 1130, 510, 400, and 370 mg per 100 g of soil by the treatment with 2.0% carbon each of rice straw, hardwood barks, sawdust, softwood barks, and peat moss. The rates of their decomposition accounted for 41, 15, 7, 5, and

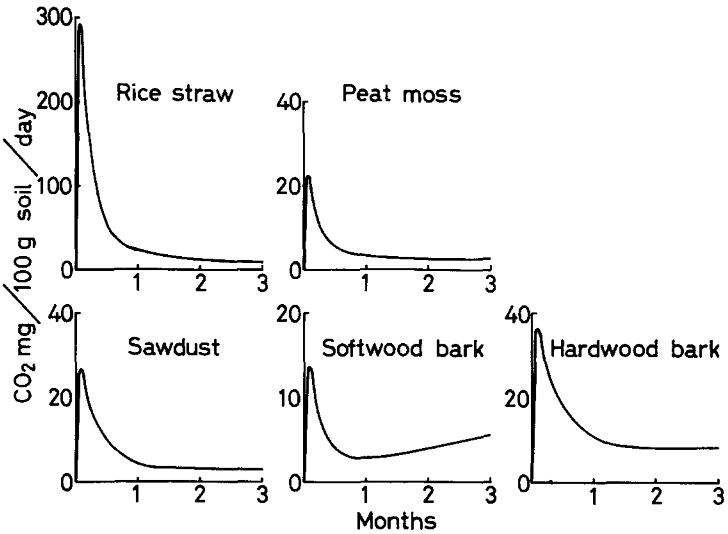

Fig. 1. CO_2 discharge during the incubation with 2.0% of various organic matters' carbon. Incubation temperature at 30°C.

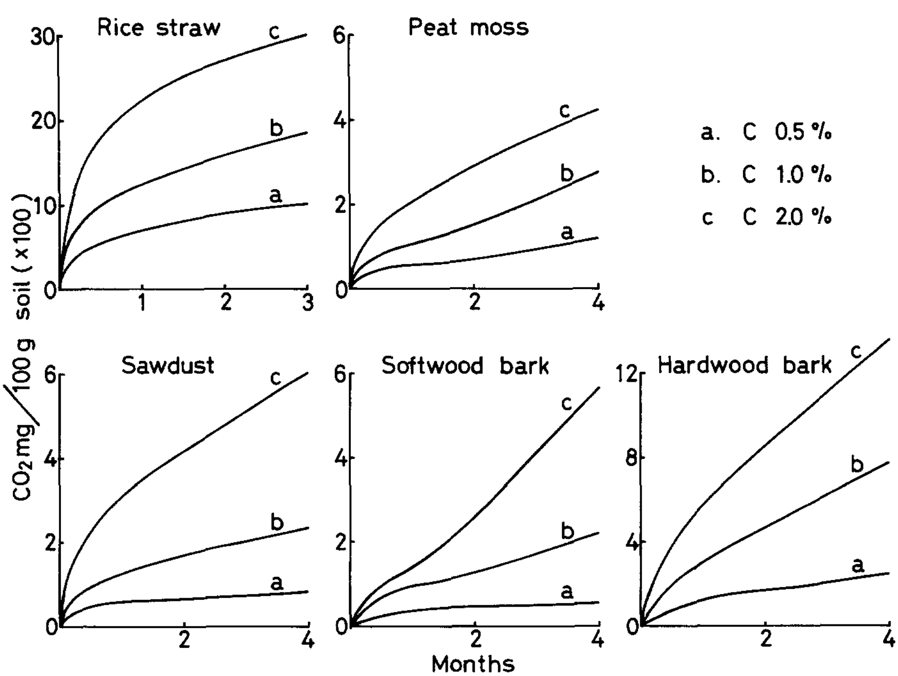

Fig. 2. Cumulative discharge of CO_2 from the soil incubated with various organic matters. Incubation temperature at 30°C.

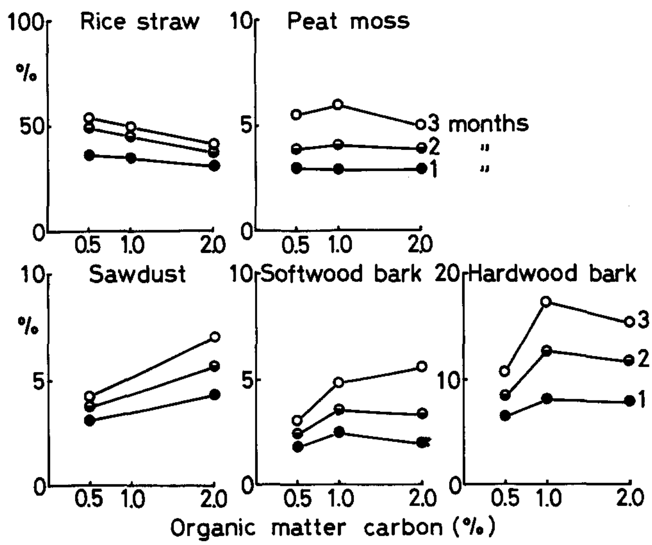

Fig. 3. Decomposition rate of various organic matters applied to the soil after different periods of incubation.
Incubation temperature at 30°C.

5%, respectively. The decomposition rates varied slightly according to the amounts of carbon added to the soil (Fig. 3). In case of rice straw, the less carbon added, the higher the decomposition rate; but in case of woody matter, the decomposition rate remained unchanged or it showed a slight upward trend in accordance with the increased amounts of the carbon. In case of peat moss, the decomposition remained at a nearly uniform rate, irrespective of the amounts of the carbon.

The fertilizer nitrogen accelerated the CO_2 discharge, to some extent, in case of the treatment with 1.0 and 2.0% of rice straw carbon. On the other hand, in case of the treatment with 0.5 and 1.0% of peat moss carbon, the CO_2 discharge was unchanged, but in case of the treatment with 2.0%, it showed a decrease. In case of the treatment with 0.5% of woody matter carbon, the CO_2 discharge showed a decrease, but in case of the treatment with 1.0 and 2.0%, it showed a slight increase. Allison *et al.*[2,3] reported that hard woods decomposed more readily than soft woods and wood particles decomposed more readily than the barks, and that in case of not-easily-decomposed ones, no effects of the fertilizer nitrogen on the acceleration of the decomposition process were observed because of the sufficient supply of the soil nitrogen.

Based upon the above facts, it was shown that nitrogen was not so important as a limiting factor in the decomposition of rice straw and it was considered that in the case of peat moss containing sufficient nitrogen and in the case of not-easily-decomposable wood particles, no additional nitrogen was needed for their decomposition process at normal temperatures.

Experiment 2. The morphological changes in the NO_3–N (which was applied to the soil together with organic matter) during the incubation were examined by making the ^{15}N analysis. Fig. 4 indicates the turnover rates of $^{15}NO_3$–N to the organic nitrogen fraction. It could be seen that the patterns of immobilization for the applied nitrogen varied according to respective organic matter. In case of rice straw, the greater the carbon content, the higher the immobilization rate. In case of treatment with 2.0% of rice straw carbon, the applied nitrogen was almost completely transformed into the organic nitrogen within 15 days. It was observed that during the incubation, 71 to 77% of the immobilized nitrogen remained in the form of non-distillable acid-soluble nitrogen fraction. It was thought that the greater part of the fertilized NO_3–N has transformed into amino acid-nitrogen in the soil[4]. Even in case of treatment with 0.5 and 1.0% of the rice straw carbon, the immobilization proceeded for one month after application, but

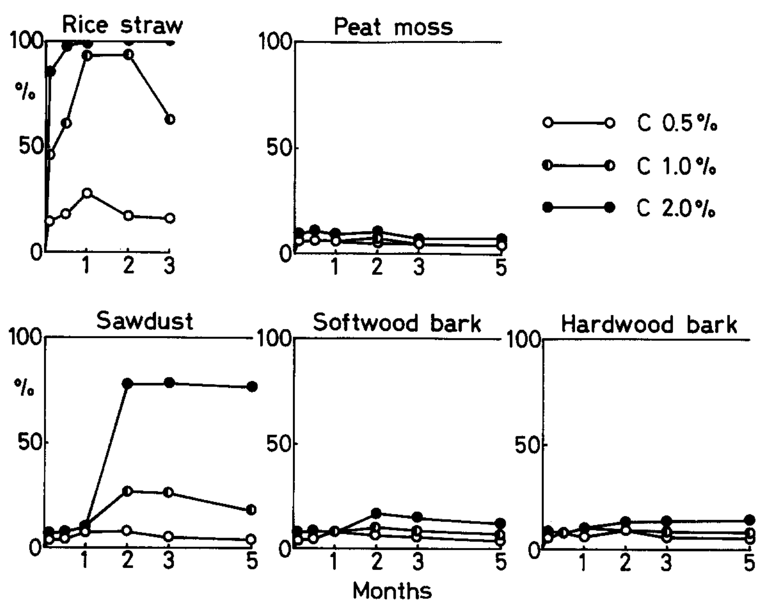

Fig. 4. Percentages of fertilizer nitrogen incorporated into organic nitrogen after different periods of incubation with various organic matters.
Incubation temperature at 30°C.

thereafter the remineralization of nitrogen could be found. The remineralization of nitrogen was thought to be due to the decomposition of the non-distillable acid-soluble nitrogen fraction. It was said that when the C/N ratio was higher than 20, the immobilization showed a preponderance, while when the C/N ratio was lower than 20, the mineralization showed a preponderance[13]. Information from the decomposition process of organic matter and that from the immobilization process of ammonium nitrogen as well as from the C/N ratio of the remaining organic matter, indicate that the C/N ratio of 13 was the final equilibrium value[8]. In case of our experiments, it was established that the C/N ratios of the undecomposed organic matter were lowered at the end of a 2 month period to 13–14 and 17–20 by the treatment with 0.5 and 1.0% and with 2.0% of rice straw carbon, respectively. Based upon the results, it could be understood that in the former case, mineralization proceeded, while in the latter case immobilization was still preponderant.

In the case of peat moss, the rate of the fertilizer nitrogen showed a low transfer to the organic nitrogen fraction. Ninety to 95% of the applied nitrogen remained in the form of the inorganic nitrogen after ending the period of incubation. Nowosielskie *et al.* tried the same incubation tests and reported that all the added nitrogen were collected in the form of inorganic nitrogen[10]. It was considered that peat moss was not readily subjected to microbial decomposition and had a superiority in the improvement of physico-chemical properties of the soil.

In the treatment with 2.0% of the sawdust carbon, about 80% of the fertilizer nitrogen was immobilized within 2 months. However, the rates of immobilization were only 10% and 25% in the treatment with 0.5% and 1.0% of the sawdust carbon, respectively. Therefore, the plant nitrogen deficiency could be avoided by the application of sawdust together with fertilizer nitrogen at the C/N ratio of 25.

In cases of softwood and hardwood barks, the rate of the fertilizer nitrogen which was incorporated into organic nitrogen fractions was quite low. The rate accounted for 20% or less, even in case of the treatment with 2.0% of the bark carbon. Accordingly, supplemental nitrogen should be applied at the rate of 20% or more, at the time of application of barks to the soil.

Experiment 3. Data for the total N and fertilizer N taken up by the plants are given in Fig. 5. In Fig. 5, the results of tests made by the treatment with 2.0% of organic matter carbon are shown. Approximately 80 mg of nitrogen was absorbed by the plants in the control plot and the fertilizer nitrogen accounted for 19 to 20 mg of them. On the 90th day, however, it showed a slight decrease. Such a decrease might be due to denitrification in the soil during the incubation[5].

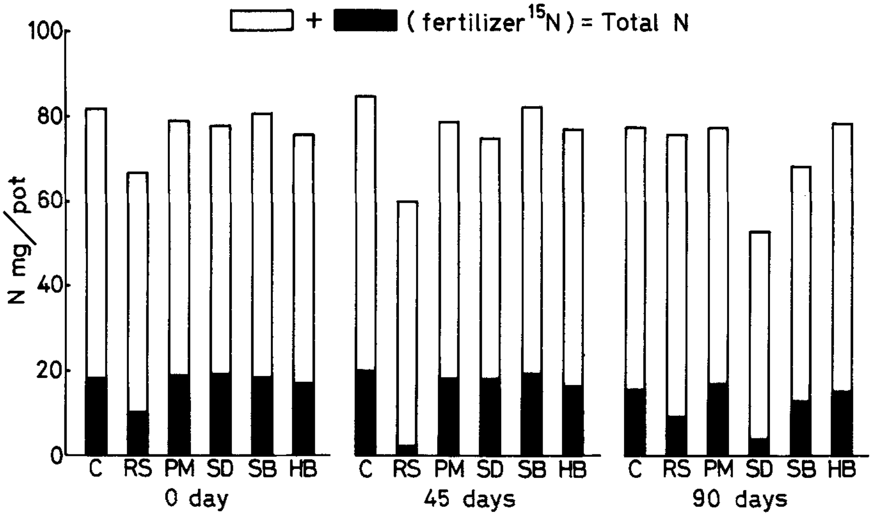

Fig. 5. Plant uptake of nitrogen as affected by the incubation with 2.0% of various organic matters' carbon. Incubation temperature stood at 30°C and rye plants were grown at 20–22°C.
C: Control, RS: Rice straw, PM: Peat moss, SD: Sawdust, SB: Softwood bark, HB: Hardwood bark.

In case of rice straw, the amount of the fertilizer nitrogen absorbed by the plants showed a marked decrease until the 45th day, but from the 90th day on, it began to increase again. This would mean that the immobilized nitrogen was remineralized and absorbed by the plants.

In case of peat moss, the amount of the nitrogen absorbed by the plants was constant, showing a similar tendency to that in the control plot. In case of sawdust, it showed a sudden decrease in the amount of the absorbed nitrogen on the 90th day, thus developing apparent nitrogen-deficiency symptoms. In the case of barks, it showed a slight decrease in the amount of the absorbed nitrogen on the 90th day, but the fertilizer nitrogen accounted for 70 per cent.

Also in case of the treatment with 0.5 and 1.0% of each organic matter carbon, the same tendency was seen, but the rate of the absorbed fertilizer nitrogen was higher than that in case of the treatment with 2.0% of each organic matter carbon. Even in the case of rice straw, which is readily decomposed, the rate of the absorbed fertilizer nitrogen accounted for 50%, and in cases of other matter, it accounted for nearly 70% or more.

Based upon the experimental results mentioned above, the following conclusions can be drawn:

In those cases where rice straw was applied, it was easily decomposed and the immobilization of the fertilizer nitrogen made rapid progress. As a result, some nitrogen-deficiency symptoms could be observed, but as the mineralization made gradual progress, the nitrogen-deficiency symptoms could be alleviated.

Contrarily, peat moss was not readily subjected to the action of microorganisms, and most of the fertilizer nitrogen remained in the form of inorganic nitrogen. It was seen that the nitrogen-deficiency of a plant might not readily take place when peat moss was applied.

In case of the incubation with sawdust, the decomposition had slow progress and the fertilizer nitrogen had been immobilized by degrees. As a result, some nitrogen-deficiency symptoms developed quite obviously. The plant nitrogen-deficiency, however, could be avoided by the application of sawdust together with the fertilizer nitrogen at the C/N ratio of 25.

The rate of the decomposition of barks is very low. Since the immobilization rate accounted for 20% by the treatment with 2.0% of the bark carbon and any remineralization could not be expected, supplemental nitrogen is required to be applied at the rate of 20% or more, at the time of the application of the barks to the soil.

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