Patterns of Nitrogen Release in Paddy Soils Predicted by an Incubation Method

By TAKASHI YOSHINO* and YOSHIMITSU DEI**

* Environment Research Division, Central Agricultural Experiment Station
** Agricultural Chemistry Division, Hokkaido National Agricultural Experiment Station

Introduction

Nitrogen supply potentials of soils have been evaluated with incubation methods in which the effect of air-drying on ammonification or the effect of elevated soil temperature has been of specific concern[1,2].

The incubation methods, as mentioned by Harmsen et al.[3] are simple, rapid and not expensive. However, it is very difficult to correlate the results obtained with the actual field data for in the incubation tests the nitrogen release is measured merely under the optimal condition during a comparatively short period of a week or two. Hence, the results are meaningful only when relative nitrogen supply potentials are discussed among different soils.

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

We had examined at first the test method revealing the process of soil nitrogen release, and introduced a concept of "effective temperature". This concept was then evaluated by comparing with the results in the field tests and by using the soils pretreated differently. Patterns of soil nitrogen release were further determined with different paddy soils from all over Japan.

Examination of the incubation method

In an attempt to evaluate the mineralization of the soil organic nitrogen in the paddy soils during the rice-growing season, submerged soils placed in the closely stoppered and unstoppered test tubes (anaerobic and aerobic condition, respectively) were incubated at different temperatures for a prolonged period and released ammonium nitrogen was determined.

Under the anaerobic condition the release of ammonium nitrogen was apparently observed even after the incubation of 10 weeks and the higher the incubation temperature, the more the release of ammonium nitrogen.

On the contrary, the release of ammonium nitrogen was levelled off under the aerobic condition within a comparatively short period probably due to the denitrification loss of nitrogen which occurred in the oxidized zone of the soil.

The aerobically incubated soil accumulated lesser amounts of ammonium nitrogen than the anaerobically incubated soil; the difference was more marked at the lower temperature or in the non-air dried original soil in which denitrification loss was more appreciable.

These findings led us to the conclusion that the anaerobic condition should be employed in the long-term incubation of the paddy soil for the determination of the nitrogen release.

In the succeeding studies, we employed the following condition: 10 to 20 g of soil sample were placed in a glass test tube, 26 mm inner diameter and 100 mm depth, added with water, stirred thoroughly, closed tightly with rubber stopper, and incubated at the controlled temperatures.

Effect of incubation temperature on the nitrogen release

Soil organic nitrogen mineralizes faster at a higher incubation temperature; a rise in temperature of 10°C increases the rate of mineralization two to four times (2, 4).

Fig. 1 shows the effect of the temperatures on the release of ammonium nitrogen in the submerged paddy soil incubated under the anaerobic condition.

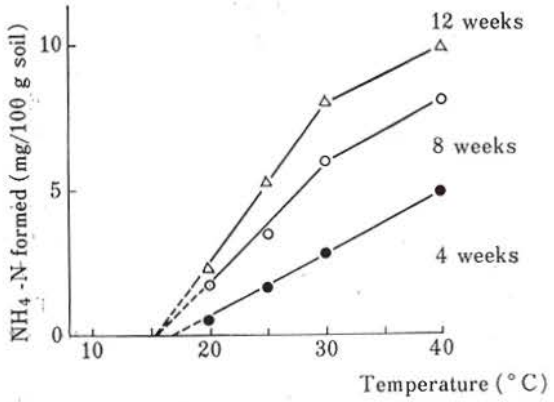

Fig. 1. Release of ammonium nitrogen as affected by temperature in the anaerobic incubation (non-air dried Konosu paddy soil)

Ammonium nitrogen was increased with the time of the incubation, and was proportional to the temperature within the range from 20 to 30°C. The result in Fig. 1, however, was not sufficient to understand the effect of temperature and duration of the incubation inclusively. Therefore, we then introduced a new concept of the effective temperature.

Effective cumulative temperature

In Fig. 1, the extrapolated three curves are likely to intersect the horizontal line at a point around 15°C, where the release of ammonium nitrogen is suggested to become null. That is to say, the soil temperature is effective for the mineralization of soil organic nitrogen only when it is over a certain critical level.

Ammonium nitrogen increased with time; the relationship, however, was not linear but followed a logarithmic curve.

Based on these two findings, we proposed the following approximate equation expressing the relation of ammonium nitrogen release with temperature and duration of the incubation;

$$Y=k[(T-T_0)D]^n \quad \ldots\ldots\ldots \quad (1)$$

where Y is the ammonium nitrogen released, T incubation temperature (°C), T_0 the minimum threshold temperature, D the duration of the incubation (days).

The effective temperature is defined by $(T-T_0)$, and summation of effective temperature by $(T-T_0)\times D$ (degree·days).

The coefficient, k, is related to the nitrogen supply potential of the tested soil; if the summation of effective temperature in the equation (1) is expressed by the ratio to the value during the rice growing period, for example 1050 degree days, the coefficient k is equivalent to the ammonium nitrogen released at the summation of effective temperature of 1050 degree days. The exponent, n, is a constant relating to the pattern of ammonification.

In the incubation test, the values T, D and Y and known or measureable but in order to calculate k and n, we had to give an adequate value to T_0. This minimum threshold temperature, T_0, had already been estimated to be about 15°C by extrapolating the curves in Fig. 1 but the best approximate was calculated by using the least square method from the data of ammonium nitrogen released during the different periods of incubation at temperatures from 20 to 30°C.

All the calculated values fell in the range from 13 to 16°C, regardless of soils; it indicated that T_0 was a constant and 15°C was the most adequate value for it.

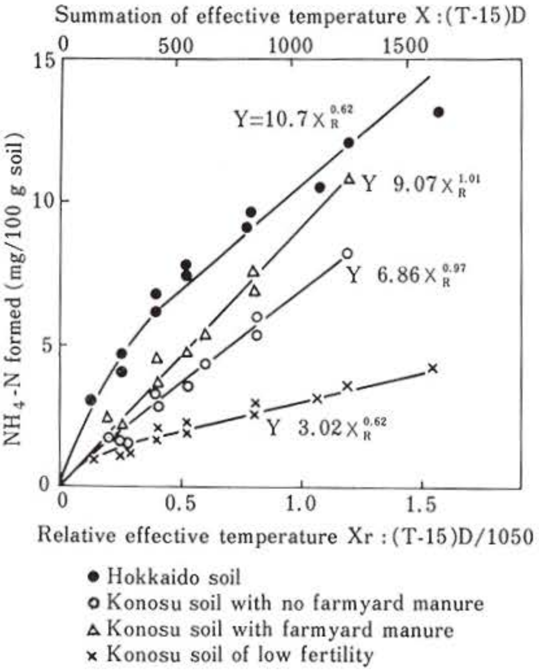

Fig. 2. Release of ammonium nitrogen from submerged paddy soils as affected by the effective temperature (non-air dried soils)

As seen in Fig. 2 showing the relation between the effective temperature and the ammonium nitrogen released in the submerged soils of different fertility levels, the equation (1) is useful for simplifying the relations and quite satisfactory as an approximation for the ammonification process of soil organic nitrogen.

By determining the ammonium release pattern at a certain temperature, e.g. at 30°C in an incubation test, we can predict by using the equation the release pattern for ammonium nitrogen at different temperature, e.g. at 20 or 25°C.

Comparison of the incubation and the actual field data

Soil temperature is not controlled but varies in the actual fields, daily and seasonally. Embedding the stoppered bottles packed with the submerged soil sample in the topsoil of paddy field, we compared the release of am-

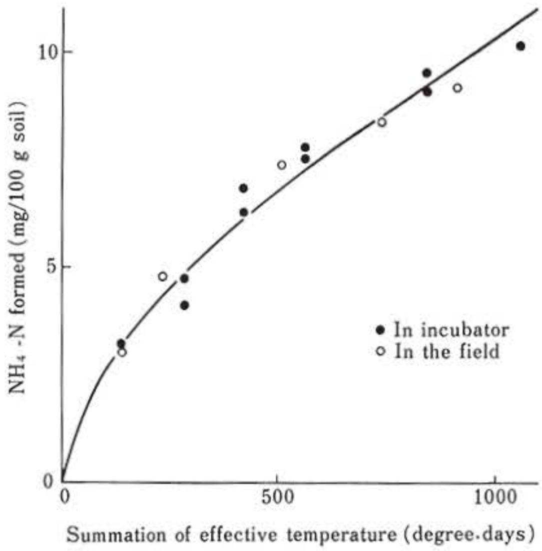

Fig. 3. Release of ammonium nitrogen from submerged soils anaerobically incubated in incubator and kept in the field (Konosu paddy soil)

monium nitrogen from the soil kept in an incubator and in the field.

As seen in Fig. 3, release of ammonium nitrogen was governed by the effective temperature calculated from the daily average temperature, and the good agreement was observed with two curves for the ammonium release patterns determined in the incubation test and in the field as far as the comparison was made on the basis of the effective temperature. The result led us to the conclusion that the mineralization process for soil organic nitrogen could be predicted with the results obtained in the incubation method.

Effect of pretreatment of soils on the mineralization of soil nitrogen

Release of ammonium nitrogen in the submerged soils varies with the pretreatment of the soils. The most marked effect was observed with the air-drying of the soil sample before the submergence.

Even with the non-air dried wet soil the ammonification process varied whether it was submerged immediately after the sampling or submerged after having been stored for a certain period. The effect of such pretreatment on the ammonium release after submergence is shown in Fig. 4.

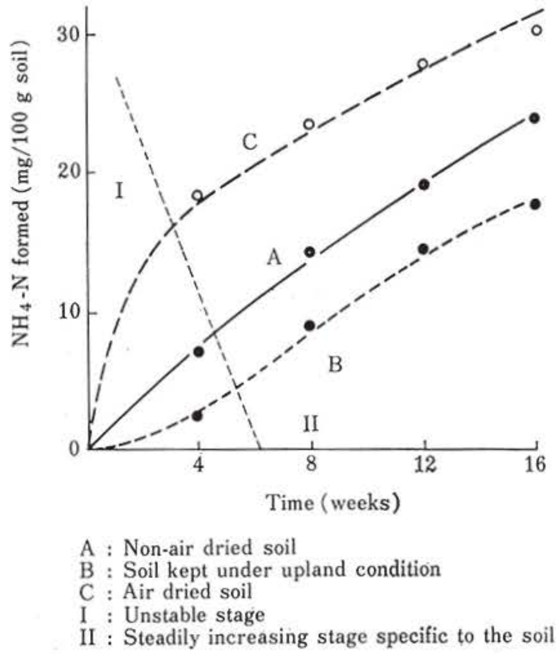

Fig. 4. Effect of pretreatment on the release of ammonium nitrogen from submerged soil

In case the air-dried soil was submerged, ammonium nitrogen was released rapidly in the first four weeks at 20°C, then it paralleled the curve for the non-air dried wet soil.

When the original soil had been kept under the upland field condition, the lag period was observed for about four weeks, after the submergence at 30°C.

The decrease in the ammonium release during the lag period was approximately equivalent to the nitrified nitrogen during the upland period.

Even with soil having been kept under the upland condition, the release of ammonium nitrogen, however, was restored to the level for the original soil after four weeks of the incubation.

This suggested the release of ammonium nitrogen proceeded in two stages; (1) the unstable stage I, affected easily by the pretreatment such as air-drying or keeping under the upland condition, and (2) the steadily increasing stage II, specific to the soil and not easily affected by the pretreatment.

Patterns of ammonium release in different paddy soils

The mineralization patterns for soil nitrogen was investigated by the incubation method with 24 paddy soils different in genetic and fertility conditions from all over Japan. The most characteristic was the fact that the release of ammonium nitrogen was always more from the soils in the colder districts than from those in the warmer regions.

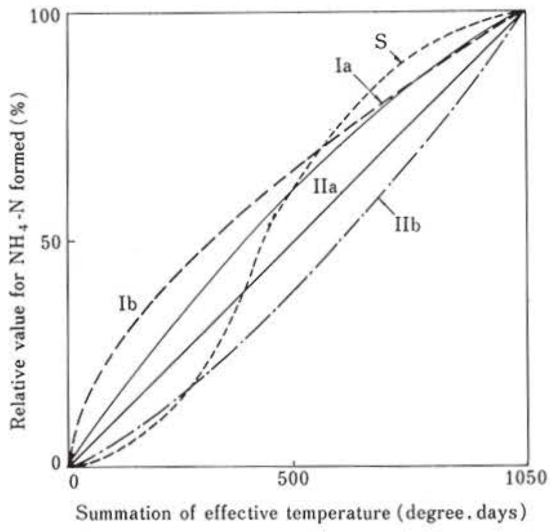

Fig. 5. Patterns of the ammonium nitrogen release from different soils

As seen in Fig. 5, we can recognize five groups according to the patterns of the ammonium nitrogen release. Group Ia was most frequent; the soils in this group were mostly of the fine-textured one. Coarse-textured soils belonged to group Ib, and the humic volcanic ash soils to group IIa. Groups S was found among the very fine-textured soils.

Conclusion

The effect of the temperature on the release of ammonium nitrogen in submerged soils is simply understood with the concept of the effective temperature. This new concept makes it possible to express the time course and the extent of the ammonification process with an approximate equation.

The equation is proved to be applicable not only to the results of the incubation test but also to the field data with daily and seasonal variation of the temperatures.

As the nitrogen supply potentials for paddy fields of Japan are most likely to be controlled by the soil temperatures after the flooding, this concept of the effective temperature provides a useful tool for the interpretation and prediction of the nitrogen supply patterns in the paddy soils.

References

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