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Absorption of Fertilizer and Soil Nitrogen by Rice Plants under the Various Cultural Conditions of Different Paddy Fields.

I. Relationships between the Rate of Basal Nitrogen and Nitrogen Absorption by Rice Plants.

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Summary

Field experiments using tagged ammonium sulfate were conducted to study the absorption of fertilizer and soil nitrogen by rice plants in Odawara and Takadate fields of which surface soils showed great differences in CEC, clay mineral composition, ammonification, etc. The experimental plots consisted of three levels of basal nitrogen: no-nitrogen, standard, and high. Rice plants were transplanted at the standard spacing in early and late May. Sampling of plant and soil was carried out at the intervals of about 10 days after the transplanting.

The amounts of soil ammonium nitrogen, reflecting the levels of basal nitrogen, decreased after the transplanting and disappeared in almost all of the plots at the end of June. The proportion of fertilizer nitrogen in soil ammonium nitrogen was greater in the plots with high level of basal nitrogen and decreased with the lapse of time. Compared with the Odawara soil, the Takadate soil showed a considerably higher proportion of fertilizer nitrogen.

The amounts of nitrogen absorbed by rice plants in the plots with the basal nitrogen increased gradually in May and rapidly in June. The absorption of basal nitrogen by rice plants was almost finished at the end of June. The ratios of the amounts of fertilizer nitrogen to those of total nitrogen absorbed by rice plants were greater in the plots with the high rate of basal nitrogen and at the early stage of growth.

The recoveries of basal nitrogen in the rice plants were greater in Takadate (42% in the standard rate, and 36% in the high rate) than in Odawara (31%, and 27%, respectively). On the other hand, the amounts of soil nitrogen absorbed by rice plants were larger in Odawara than Takadate.

Though the amounts of basal nitrogen absorbed by rice plants were much less than those of soil nitrogen, it was shown that basal nitrogen played an important role in the rapid establishment and growth of seedlings after transplanting. On the other hand, soil nitrogen was also of great importance for rice growing, even when much nitrogen in commerical forms was used.

Nitrogen is commonly the most important nutrient applied to soil and needs the most elaborate application technique. The remarkable increase in rice yield per unit area during the past 20 years in Japan is attributable in large measure to the heavy use of nitrogen in commercial forms (1). Therefore, the fertility of paddy soils has been somewhat neglected by the farmers who prefer to use much chemical fertilizer.

Apparently, the recent data of nitrogen balance between soil and plant has become more accurate by the adoption of ^{15}N-tracer technique. Reviewing the papers concerning rice field experiments using ^{15}N-tagged nitrogen, however, there are a few results which include plant and soil analyses done at different intervals after the application (2–6). The purpose of the present series of research using ^{15}N-tracer technique is to ascertain the fate of fertilizer and soil nitrogen in the paddy field under the various cultural conditions in different paddy fields and to estimate the role of nitrogen in the growth of rice plants.

Materials and Methods

1. *Properties of the soils in the experimental fields of Miyagi Prefectural Agricultural Experiment Station.*

Field experiments were conducted in the Odawara field in 1971 and 1972, and in the Takadate field in 1973 and 1974. The properties of the soils of these fields are given in Table 1. Though both paddy soils are relatively poor in drainage, there are remarkable differences in several properties between the plowed layers of these soils. Since Odawara soil was dressed with the soil developed on the Tertiary tuff, the soil has much less clay content and cation exchange capacity in the plowed layer than Takadate soil. Though the total nitrogen contents of these soils are almost the same, the amount of ammonia formed by incubation is much less in Takadate soil, suggesting a lesser supply of soil nitrogen to rice plants. Compared with the various paddy soils in the Tohoku district (7), it can be said that Odawara soil is rather similar to the most common paddy soils in Tohoku

TABLE 1. *Description of Paddy Soil*

Field	Depth (cm)	Texture	Soil color
Odawara	0–18	SCL	gray
	18–34	LiC	dull yellow orange
	34–43	〃	yellowish gray
	43–	〃	dark greenish gray
Takadate	0–10	LiC	brown
	10–25	〃	dark brown
	25–	〃	grayish brown

*: reachion with $\alpha\alpha'$-dipyridyl reagent.

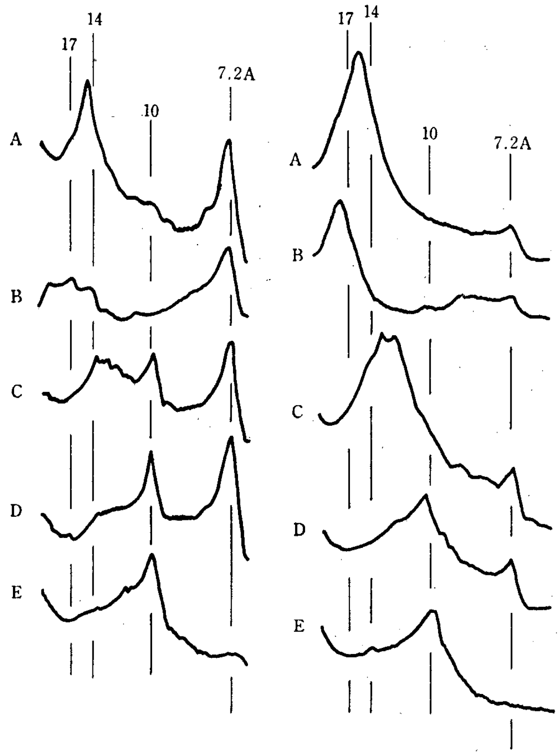

FIG 1. X-ray diffraction patterns of <2μ clay fractions of the plowed layers of Odawara (left) and Takadate (right) fields.
A; Ca-clay. B; Ca-clay, treated with ethylene glycole. C; K-clay, air-dried. D; K-clay, heated at 300°C. E; K-clay, heated at 550°C.

district, while the Takedate soil is considerably different from them.

Not only the surface soil but also the subsoil of each paddy soil shows almost the same X-ray diffraction patterns of the clay fractions. As seen in Fig. 1, the clay fraction of Odawara soil consists of mainly expansible 2:1 layer silicates, 2:1 to 2:1:1 intergrade and metahalloysite. On the other hand, the clay fraction of Takadate soil is predominated by montmorillonite. Reflecting the difference in

Profiles and Their Properties.

Presence of Fe^{2+}*	CEC me/100 g	T-C %	T-N %	Ammonification** NH_3-N mg/100g
+	20.8	2.04	0.17	6.8
±	27.2	0.71	0.08	
−	24.0	1.45	0.19	
−	26.2	1.83	0.19	
−	40.8	1.72	0.12	4.3
−	35.2	2.62	0.24	
−	37.9	1.18	0.09	

**: after 4 weeks incubation at 30°C.

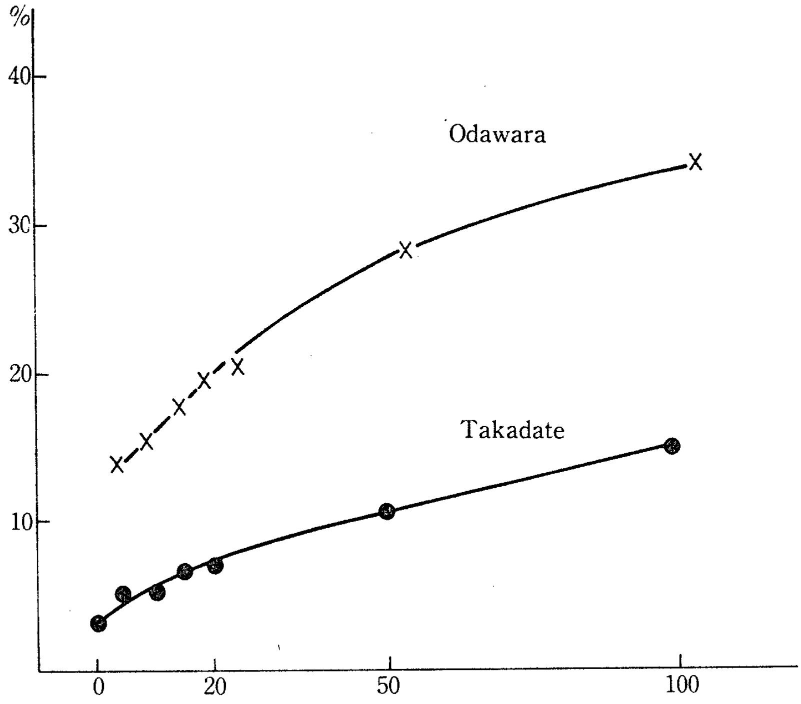

FIG 2. Percentages of ammonium nitrogen existing in the soil solution (soil; water=1:2)

clay mineralogical composition, the plowed layers of both soils show remarkable difference in the ammonia absorption equilibria as seen in Fig. 2. The amount of ammonia existing in the solution is much less in Takadate soil, suggesting a more gradual loss of fertilizer nitrogen in the plowed layer and greater absorption of fertilizer nitrogen by rice plants. However, when small seedlings, or seedlings of third leaf age which are considered to be relatively poor in nutrient absorption, are transplanted early in the Takadate field, the seedlings are supposed to be inferior to larger seedlings, or seedlings of sixth leaf age in the early stage of growth.

From the mentioned above, it is assumed that the amount of absorption of fertilizer nitrogen by rice plants is greater in the Takadate soil than in Odawara soil. On the other hand, the amount of absorption of soil nitrogen by rice plant is greater in the Odawara soil than in the Takedate soil.

2. *Design of field experiment*

The design of field experiments is shown in Table 2. The experimental plots consist of three levels of basal nitrogen; no-nitrogen, standard (6–7 Kg N/10a) and high (12–15 Kg N/10a). The standard level is commonly used by the farmers in Miyagi prefecture. The area of each plot was 40 m^2 (8×5 m), where small sub-polts (36 cm$\times$60 cm) surrounded by wooden plates were fixed. Ammonium nitrogen enriched with the various amounts of ^{15}N was applied to the sub-plots.

TABLE 2. *Design of Field Experiment*

Year	Experimental field	Basal application (Kg/10a)			Transplanting date	Rice variety	Kind of seedling	Numbers of seedling per hill
		N	P_2O_5	K_2O				
1971	Odawara	0 7 15	7 7 7	7 7 7	May 24	Sasaminori	large	3 3 3
1972	Odawara	7 15	7 7	7 7	May 6	Sasaminori	large	3 3
1973	Takadate	0 6 12	7 7 7	7 7 7	May 1	Sasanishiki	small	5 5 5
1974	Takadate	0 7 15	7 7 7	7 7 7	May 25	Sasaminori	large	3 3 3

Kind of chemical fertilizers;
N; ammonium sulfate P_2O_5: calcium superphosphate K_2O; potassium chloride
all the fertilizers were applied to the depth of 10cm.
Atom percentage of ^{15}N in ammonium sulfate;
2.1% for the analysis of soil ammonia and plant nitrogen. 10 to 11% for the determination of residual nitrogen in paddy soil.
Seedling;
Large; fifth to sixth leaf age Small; third leaf age
Spacing; 30×12 cm

Sampling of plant and soil was carried out at intervals of about 10 days after the transplanting until the end of June or the beginning of July. Soil ammonia extracted with 1N KCl solution was determined by the distillation method. Total nitrogen of plant and soil was determined by Kjeldahl method. The isotopic ratio of nitrogen was measured by a mass spectrometer (R-M-I 2 type).

3. *Climatic data of rice growing season.*

Climatic conditions influence the mineralization of soil organic nitrogen and the absorption of fertilizer and soil nitrogen by rice plants. Fig. 3 shows the mean temperature and duration of sunshine measured during the rice growing season from 1971 to 1974. There was no unusual change in the weather patterns during this period.

Results and Discussion

Fig. 4 shows that the amounts of soil ammonium nitrogen are nearly coincident with the levels of basal nitrogen in both Odawara and Takadate fields. Though it is small in amount, soil ammonia of the no-nitrogen plot in the Odawara field is about twice as much as that of the same plot in Takadate. From this fact, it is

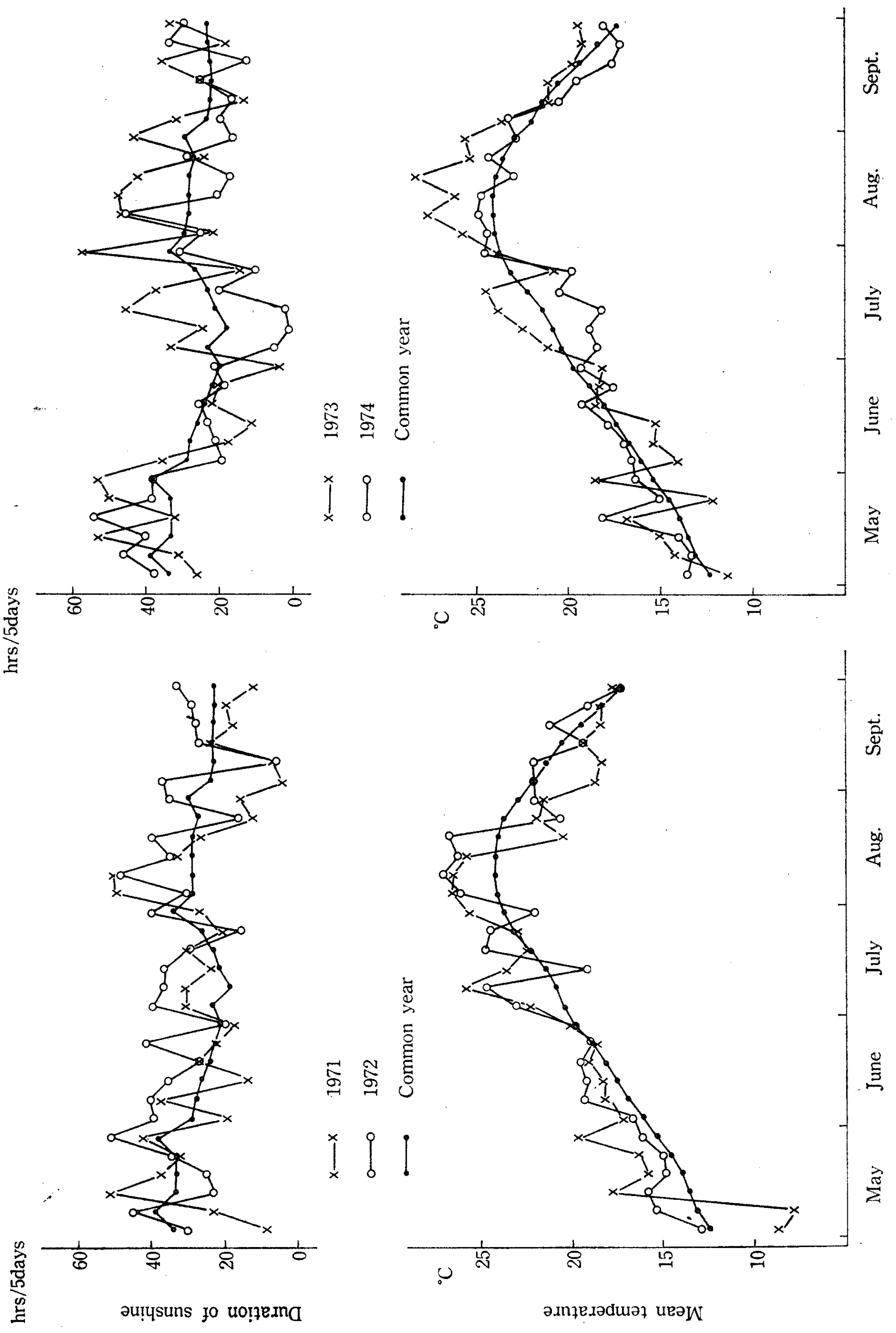

FIG. 3. Climatic data during the rice growing season.

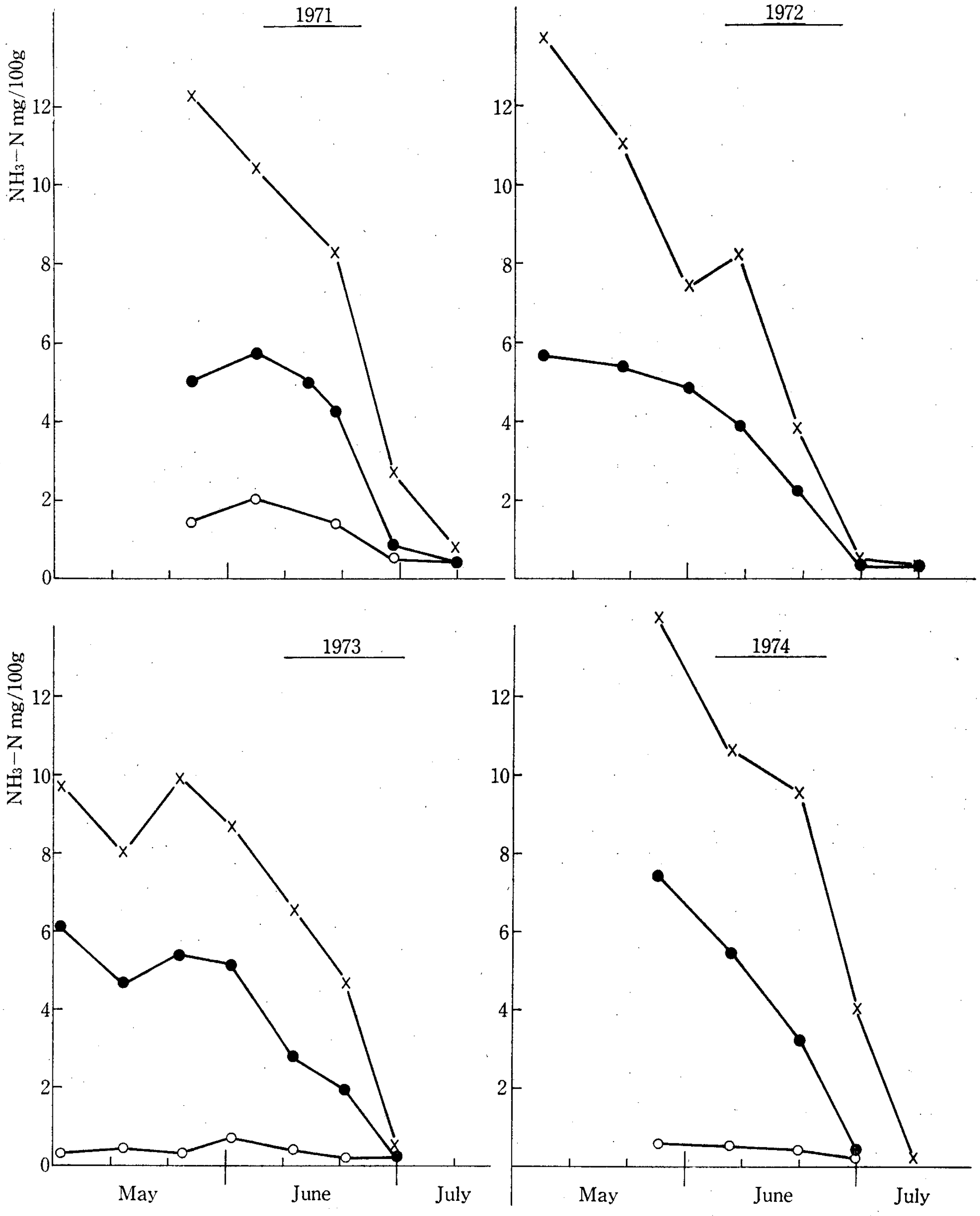

Fig. 4. The amounts of soil ammonium nitrogen.
○——○ No-nitrogen ●——● Standard rate ×——× High rate

thought that the supply of soil nitrogen to rice plants will be greater in Odawara than in Takadate.

The amounts of soil ammonia in all the plots supplied with basal nitrogen tend to decrease after transplantation. The decrease of soil ammonia becomes more rapid after the beginning of June, largely because of the rapid growth of the rice plants. On the other hand, at the same time, the amounts of ammonia formed by

TABLE 3. *The Percentage of Basal Nitrogen in Soil Ammonium Nitrogen.*

Field	Sampling date	Experimental plot	
		standard level	high level
Odawara	1971 June 5	48.2%	65.9%
	June 19	32.2	55.5
	June 30	16.7	32.8
〃	1972 May 30	49.1	62.4
	June 19	37.6	50.9
Takadate	1973 June 1	67.7	79.8
	June 21	60.2	70.6
〃	1974 June 9	70.7	85.3
	June 20	56.0	81.7
	June 29	—	71.7

the mineralization of soil organic matter increases rapidly. Consequently, the uptake of soil nitrogen by rice plants also increases rapidly, as will be shown later. Soil ammonia disappeared in almost all of the experimental plots at the end of June. When the rice plants were transplanted at the common date, or the end of May, however, the amounts of soil ammonia in the plots with heavy application of basal nitrogen were still greater than two mg N/100 g of dry soil.

The percentage of fertilizer nitrogen in soil ammonium nitrogen presented in Table 3 indicates that the proportion of fertilizer nitrogen is greater in the plots with a high level of basal nitrogen than in the plots with the standard level of basal nitrogen. The decrease of the proportion with the lapse of time shows the increase of mineralization of soil organic nitrogen. It is notable that the percentages of fertilizer nitrogen in soil ammonium nitrogen are considerably greater in Takadate soil than in Odawara soil. Since there is no great difference in the amount of soil ammonia between Odawara and Takadate soils with the same level of basal nitrogen, the uptake of basal nitrogen by rice plant is supposed to be greater in Takadate than in Odawara. On the other hand, the rice plants grown on Odawara field are supposed to absorb more soil nitrogen.

The nitrogen uptake by rice plants is shown in Fig. 5 and Table 4. The amounts of nitrogen absorbed by rice plants in the plots with dosages of basal nitrogen increase gradually in May, and most rapidly in June. In order to raise a plant type which improves the light-utilizing efficiency and minimizes the lodging, the restriction of nitrogen supply at the commencement of ear-primordia formation has been demonstrated to be necessary (8, 9). Therefore, heavy use of basal nitrogen in later-transplanted plots is considered to be unfavorable for raising an ideal plant type (10). On the other hand, the nitrogen uptake of rice plants grown on the no-nitrogen plots increases gradually until the end of June. Still, the rates of nitrogen uptake by rice plants in all the plots were found to be nearly the

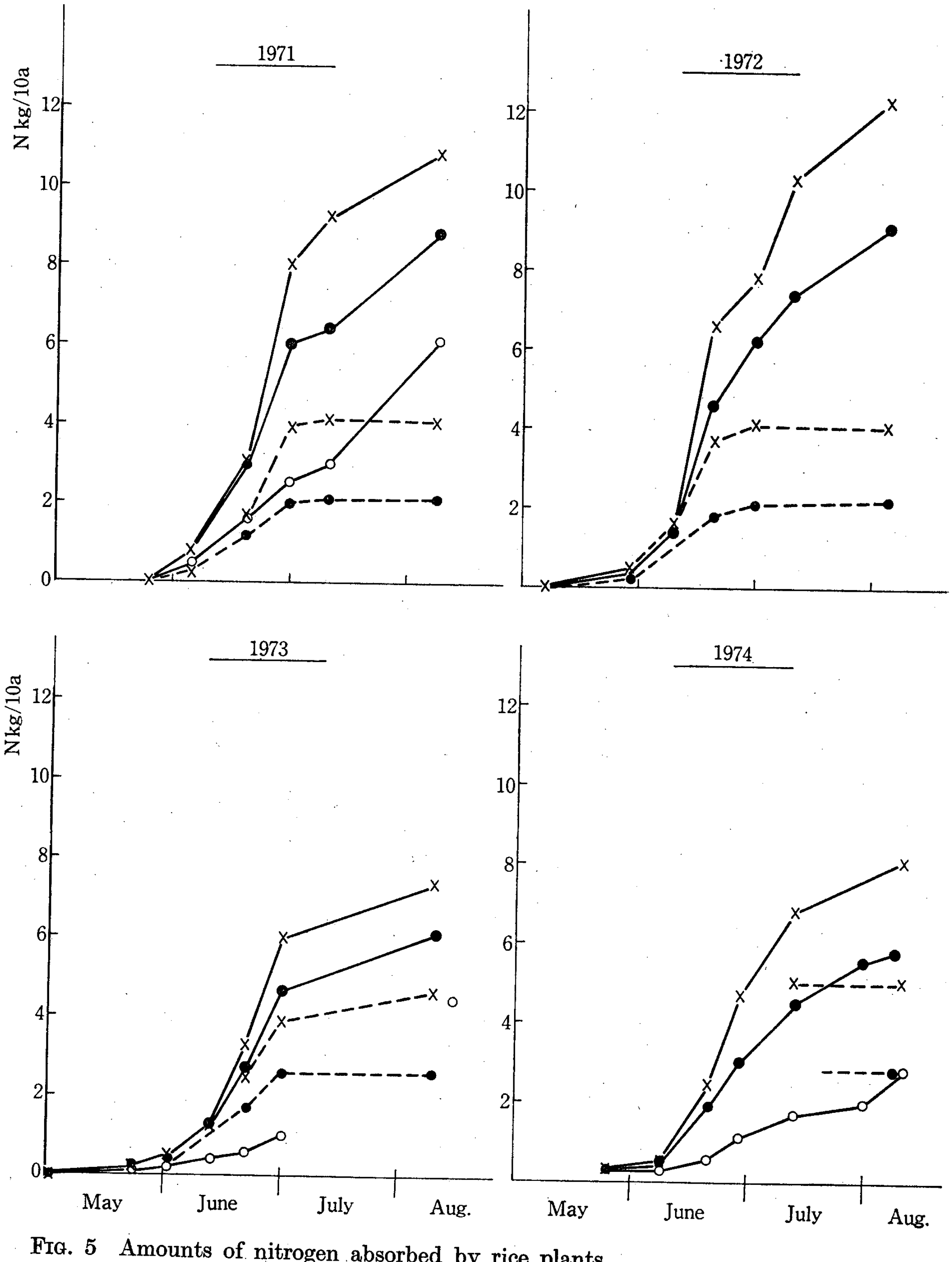

FIG. 5 Amounts of nitrogen absorbed by rice plants
o——o total nitrogen absorbed by rice plants at the no-nitrogen plot.
•——• total nitrogen absorbed by rice plants at the standard rate plot.
×——× total nitrogen absorbed by rice plants at the high rate plot.
•- - -• fertilizer nitrogen absorbed by rice plants at the standard rate plot.
×- - -× fertilizer nitrogen absorbed by rice plants at the high rate plot.

same after the end of June.

As expected from the analytical results of soil ammonia, the ratios of the amounts of fertilizer nitrogen to those of total nitrogen absorbed by rice plants are

TABLE 4. *The Ratio of Basal Nitrogen to Total Nitrogen Absorbed by Rice Plants (A) and Recover of Basal Nitrogen in Rice Plants (B).*

Field	Sampling date	(A)		(B)	
		standard level	high level	standard level	high level
	June 19	41%	56%	%	%
Odawara	1971 June 30	34	49		
	July 10	33	44		
	heading	23	37	30.6	26.9
	May 30	44	55		
〃	1972 June 19	39	56		
	June 30	34	53		
	heading	24	33	31.0	26.9
	June 1	64	76		
Takadate	1973 June 21	65	76		
	June 30	55	65		
	heading	43	62	42.7	38.5
〃	1974 July 12	—	74		
	heading	48	62	40.3	33.7

greater in the plots with high rate of basal nitrogen and at the early stage of growth (Table 4). Compared with the rice plants grown on the Odawara field, those on Takadate field show considerably high ratios.

The absorption of basal nitrogen by rice plants was almost finished at the end of June in all the experimental plots excepting those with the high rate of basal nitrogen in the Takadate field (Fig 5). After that, the rice plants absorbed only soil nitrogen.

The average amounts (Kg N/10a) of fertilizer and soil nitrogen absorbed by the rice plants until the end of June are as follows;

Field	Standard rate of basal N	
	fertilizer N	soil N
Odawara	2.1	4.1
Takadate	2.7	2.0

When the high level of basal nitrogen was applied to the Takadate field, however, the rice plants continued to absorb it until the beginning of July. These data indicate clearly that the absorption of soil nitrogen by the rice plants grown on the Odawara field was about twice as much as that by the rice plants on the Takadate. On the other hand, the removal of fertilizer nitrogen in the rice plants were greater in the Takadate than in the Odawara.

The mean recoveries of basal nitrogen in the rice plants grown on the Odawara field are 31% in the plots with the standard level and 27% in the plots with the high level. The former is the same as the mean value of eight experimental results obtained by different research workers (11). On the other hand, those in the rice plants grown on Takadate field are 42% and 36%, respectively. It is obvious that the greater recoveries of basal nitrogen in the Takadate field are due to the high CEC and clay mineral composition dominated by montmorillonite of the plowed layer.

The average amounts of soil nitrogen absorbed by rice plants until the heading stage are 7.5 Kg of N per 10 a in the plots with basal nitrogen of the Odawara field and 3.0 in those of the Takadate (Fig 5). Since certain amounts of soil nitrogen are also absorbed by the rice plants from the heading to complete ripening stage, it is evident that soil nitrogen is of great importance as a nitrogen source for rice growing, even when much more nitrogen in commercial forms is used.

The amount of soil nitrogen absorbed by the rice plants grown with basal nitrogen was much greater in the early growth stage than that absorbed by the rice plants without basal nitrogen in both the Odawara and Takadate fields (Fig. 5). This difference is considered to be due to the rapid establishment and growth of seedlings permitted by the presence of greater amount of soil ammonia in the plots with basal nitrogen. Since the amounts of soil nitrogen absorbed by the rice plants after the end of June are nearly same in all the experimental plots (Fig. 5), the amounts of soil nitrogen supplied after that can also be estimated by determining the amounts of nitrogen absorbed by the rice plants grown without basal nitrogen.

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References

1) Statistics and Survey Division, Ministry of Agriculture and Forestry, "*Multiple Correlation Analysis of Rice Yield per 10 a*" (1972) (in Japanese)
2) Wada, G. Shoji, S., and Takahashi, J., *Proc. Crop Sci. Soc. Japan*, **40**, 275 (1971) (in Japanese with English summary)
3) Shoji, S., Wada, G., Saito, K., Shinbo, I., and Takahashi, J., *ibid*, **40**, 281 (1971) (in Japanese with English summary)
4) Wada, G., Shoji S., Takahashi, J., Saito, K., and Shinbo, I., *ibid*, **40**, 287 (1971) (in Japanese with English summary)

5) Wada, G. Shoji, S., and Takahashi, J., *ibid*, **41**, 84 (1973) 42, 84 (in Japanese with English summary)
6) Takahashi, J., Shoji, S., Nogi, T., and Wada, G.. *ibid*, **42**, 91 (1973) (in Japanese with English summary)
7) Honya, K., "*Basic Conditions for High Rice Yield*", Noson-Gyoson-Bunka-Kyokai, Tokyo., p 57 (1966) (in Japanese)
8) Matsushima, S., "*Improvement and Technique of Rice Cultivation*", Yokendo Book Comp. Ltd., Tokyo, p 214 (1973) (in Japanese)
9) Matsuzaki, A., *Bull. Nat. Inst. Agr. Sci.*, Series A, **21** (1974) (in Japanese with English summary)
10) Takahashi, J., Wada, G., and Shoji, S., *Abstrats of 158th Meeting, Crop Sci. Soc. Japan*, 33 (1974) (in Japanese)
11) Dei, Y., and Yoshino, T., *Materials for the Conference of Speciallized Fields in Soil and Fertilizer*, **1** (1974) (in Japanese)