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

III. Relationship between Kinds of Rice Seedlings and Absorption of Nitrogen by Rice Plants and General Discussion

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Summary

The relationship between the kind of rice seedling and the absorption of nitrogen by rice plants was investigated in two different fields — Odawara and Takadate. Experimental plots consisted of large seedling, or fifth to sixth leaf age and small seedling, or third leaf age.

Soil ammonium nitrogen had a tendency to decrease after transplantation in all the plots. Irrespective of the levels of basal nitrogen, soil ammonium nitrogen disappeared approximately at the same time in both large and small seedlings in Odawara. On the contrary, soil ammonium nitrogen disappeared later in the small seedling plot than in the large seedling plot in Takadate. The percentage of fertilizer nitrogen in soil ammonium nitrogen was greater in the plots of Takadate than in those of Odawara.

Both large and small seedling plots in Odawara showed almost the same process of nitrogen absorption by the rice plants not only in the plot of standard level but also in the plot of high level basal nitrogen. However, the absorption of nitrogen by rice plants in Takadate was later in the small seedling plot than in the large seedling plot. The recoveries of basal nitrogen in the rice plants were 27–31 percent in Odawara, and 40–45 percent in Takadate. There was no significant difference in the recoveries between the large and small seedling plots in both fields.

The differences in the behavior of soil ammonium nitrogen and absorption of nitrogen by rice plants between the two fields were considered to be due to the following factors; the amount of soil ammonium nitrogen existing in the soil solution, the mineralization of soil organic nitrogen, and the absorption of ammonium nitrogen by rice seedling.

Summarizing the data of parts one to three of the present series of papers, general discussion was made concerning the behavior of soil ammonium nitrogen and nitrogen absorption by rice plants with special reference to the accumulated effective thermal index. Furthermore, the recoveries of basal nitrogen in the rice plants under various cultural conditions were compared.

About a thrid of the total labor necessary for rice culture is spent for the growing and transplanting of rice seedlings. Therefore, transplantation using small rice seedlings grown in the controlled house and transplanters, has rapidly spread in Tohoku district where rice culture of direct sowing is still unstable because of cold weather.

As mentioned in the previous paper (1), the remarkable increase in rice yield per unit area after World War II in Tohoku district is due in large part to the improvement of protected rice nursery care. However, much labor and material are needed for this method. Furthermore, the large seedlings (fifth to sixth leaf stage) grown in the nursery bed are unfavorable for transplanters. On the other hand, it has been reproted that the small seedlings (third leaf stage) containing some amount of albumen were favorable for transplanters and showed the most vigorous growth (2, 3).

The purpose of the present paper is to study the relationship between kinds of rice seedlings and, absorption of nitrogen by rice plants in different paddy fields. Furthermore, summarizing the data of the present series of papers (1, 4), general discussion will be made concerning the behavior of soil ammonium nitrogen and nitrogen absorption by rice plants with special reference to the accumulated effective thermal index.

Materials and Methods

Table 1 shows the design of field experiments which were carried out in the Odawara field in 1972, and in the Takadate field in 1973 and 1974. The properties of the soils of these fields were reported in detail in the previous paper (1). The experimental plots consist of two kinds of rice seedlings, namely, large, or fifth to sixth leaf age, and small, or third leaf age. The large seedlings were grown in the rice nursery bed, and the small ones, in the house where both room temperature and light intensity were controlled. The experimental procedures used for the present investigation are almost the same as reported previously (1).

Results and Discussion

Fig. 1 shows that the amounts of soil ammonium nitrogen in all the plots tend to decrease after transplantation. However, there is a notable difference between Odawara and Takadate fields. Irrespective of the levels of basal nitrogen, soil ammonia disappeared approximately at the same time in both small and large seedling plots in the Odawara field. On the contrary, soil ammonia disappeared later in the plot of small seedlings than in that of large ones in the Takadate field.

The percentage of fertilizer nitrogen in soil ammonium nitrogen is given in Table 2. It is greater in the plots of Takadate than in those of Odawara, showing that the loss of applied nitrogen and the amount of mineralized nitrogen are smaller in Takadate than in Odawara as pointed out in the previous paper (1.)

TABLE 1. *Design of Field Experiment.*

Year	Experimental field	Kind of seedling	Numbers of seedling per hill	Transplanting date	Rice variety	Basal applciation (Kg/10a)		
						N	P_2O_5	K_2O
1972	Odawara	Large	3	May 6	Sasaminori	7	7	7
		Small	5			7	7	7
		Large	3			15	7	7
		Small	5			15	7	7
1973	Takadate	Large	3	May 19	Sasanishiki	6	6	6
		Small	5			6	6	6
1974	Takadate	Large	3	May 25	Sasaminori	7	7	7
		Small	5			7	7	7

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 10 cm.
Atom percentage of ^{15}N in ammonium sulfate;
2.1% for the analysis of soil ammonia and plant nitrogen.
Seedling;
Large; fifth to sixth leaf age.
Small; third leaf age.
Spacing; 30×12 cm.

Furthermore, there is no significant difference in the proportion of basal nitrogen in soil ammonium nitrogen between the large seedling plot and the small seedling plot.

Fig. 2 shows the nitrogen absorption of rice plants from transplantation to heading time. As expected from the amounts of soil ammonium nitrogen (Fig. 1), there is also an interesting difference between Odawara and Takadate fields. Both small and large seedling plots in the Odawara field show almost the same process of nitrogen absorption by the rice plants not only in the plot of standard level, but also in the plot of high level basal nitrogen. On the other hand, the absorption of nitrogen by the rice plants in the Takadate field is later in the small seedling plot than in the large seedling plot. The amounts of soil nitrogen absorbed by rice plants are much greater in Odawara than in Takadate as previously reported.

As suggested from the percentage of basal nitrogen in the soil ammonium nitrogen (Table 2), the ratio of basal nitrogen to total nitrogen absorbed by rice plant decreased with the lapse of time after transplantation as shown in Table 3. Though the ratios of plots belonging to the Takadate field are greater than those belonging to the Odawara field, there is no significant difference in the ratios between the large and small seedling plots in the same field.

The recoveries of basal nitrogen in the rice plants are 27–31 percent in Odawara, and 40–45 percent in Takadate (Table 3). However, it can be said that

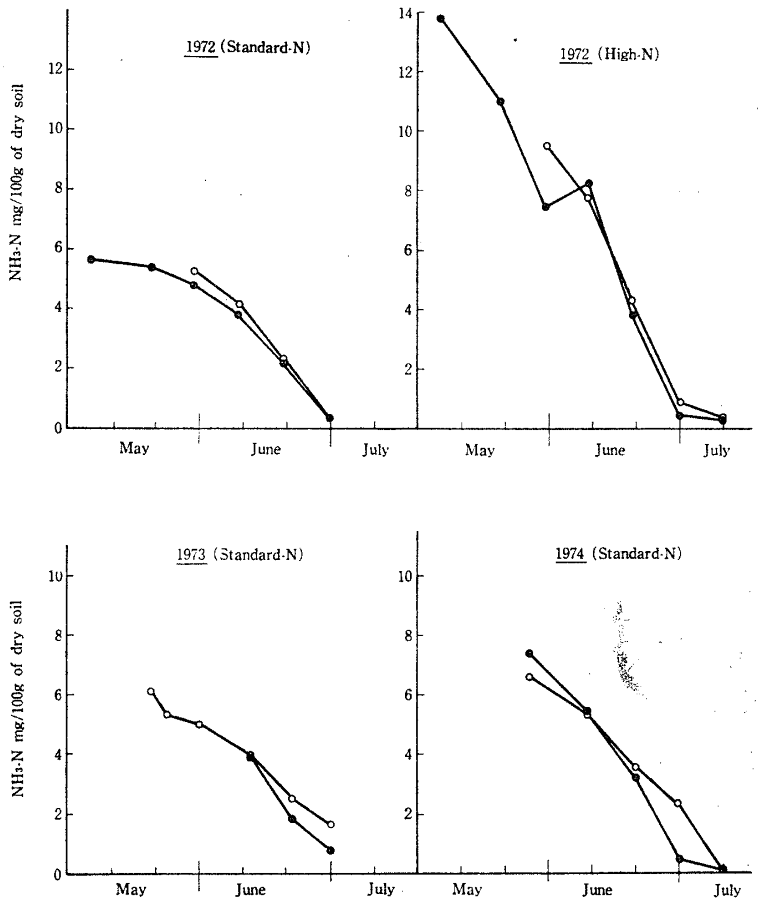

FIG. 1. Amounts of soil ammonium nitrogen.
•——•; large seedling, ○——○; small seedling

TABLE 2. *The Percentage of Basal Nitrogen in Soil Ammonium Nitrogen.*

Field	N level	Sampling date		Experimental plot: Large seedling	Experimental plot: Small seedling
Odawara	Standard	1972	May 30	49%	49%
			June 19	38	35
	High	1972	May 30	62	65
			June 19	51	50
Takadate	Standard	1973	June 1		79
			June 21	64	63
			June 30		51
Takadate	Standard	1974	June 9	71	71
			June 20	56	59
			June 29		53

there is no significant difference in the recoveries between the large and small seedling plots in both fields.

From the results mentioned above, it is in the Takdate field that small rice

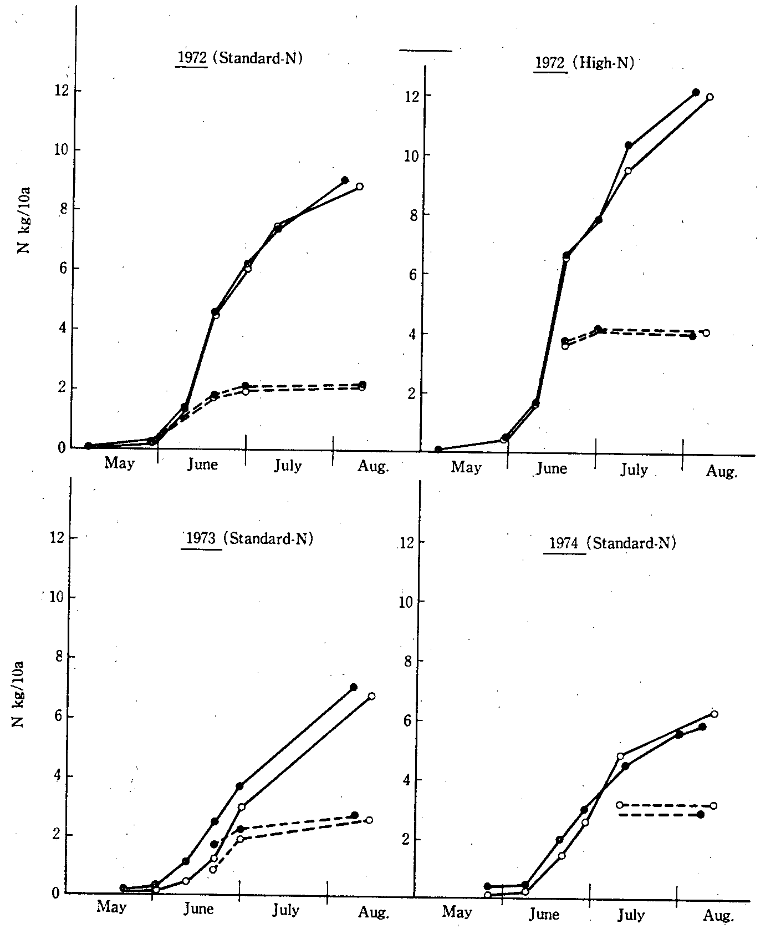

FIG. 2. Amounts of nitrogen absorbed by rice plants
•——•; total nitrogen absorbed by rice plants at the large seedling plot.
o——o; total nitrogen absorbed by rice plants at the small seedling plot
•------•; fertilizer nitrogen absorbed by rice plants at the large seedling plot
o------o; fertilizer nitrogen absrobed by rice plants at the small seedling plot.

seedlings are inferior to the large ones in the early stage of growth. This fact is most probably due to the following reasons; first, the amount of soil ammonium nitrogen existing in the soil solution is much less in Takadate soil than in Odawara soil (1), and secondly, small seedlings are relatively poor in the absorption of ammonium ions most of which are present in exchageable forms.

General Discussion

Takahashi, Wada and Shoji (5) studied the behavior of soil ammonium nitrogen and the absorption of nitrogen by the rice plants in relation to the accumulated effective thermal index (AETI) which was reproted by T. Hanyu and T. Uchijima in 1962 (6). Following the investigation of Takahashi *et al.*, the present authors also studied the problems of soil ammonium nitrogen and absorption of nitrogen by the rice plants on the basis of the data repoted so far.

The relationships between the AETI values and the amounts of soil ammonium

TABLE 3. *The Ratio of Basal Nitrogen to Total Nitrogen Absorbed by Rice Plants (A) and Recovery of Basal Nitrogen in Rice Plants (B).*

Field	Level of basal N	Sampling date		(A)		(B)	
				Large seedling	Small seedling	Large seedling	Small seedling
Odawara	Standard	1972	May 30	44%	47%	%	%
			June 19	39	38		
			June 30	34	32		
			heading	24	24	31.0	30.4
	High	1972	May 30	55	59		
			June 19	56	56		
			June 30	53	52		
			heading	33	34	26.9	27.2
Takadate	Standard	1973	June 21	70	71		
			June 30	60	64		
			heading	39	39	45.3	43.2
Takadate	Standard	1974	July 10		65		
			heading	48	51	40.3	45.0

nitrogen are given in Fig. 3. It is interesting that soil ammonium nitrogen decreased exponentially after transplantation, and almost all of it disappeared at the AETI of about 400 in all the experimental plots (A, B, C, and E in Fig. 3). Soil ammonium nitrogen derived from basal nitrogen showed the same behavior (D and F in Fig. 3). This fact suggests that the absorption of basal nitrogen by the rice plants will finish at the AETI of about 400, irrespective of the transplanting dates.

Fig. 4 shows the amounts of ammonium nitrogen derived form soil and fertilizer nitrogen in the plots where the rice seedlings were not transplanted. Some amounts of basal nitrogen were found in soil ammonium nitrogen even in August. The amounts of ammonium nitrogen derived from basal nitrogen are greater in Takadate soil than in Odawara soil. On the other hand, those from soil nitrogen are much greater in Odawara soil than in Takadate soil. These facts are well coincident with the experimental results of ammonification and ammonium absorption equilibrium of both soils (1).

As seen in Fig. 5, the amounts of nitrogen per unit area absorbed by the rice plants are closely related to the AETI in all the experimental plots. Exponential equations were obtained for the early growth stage, and linear ones, for the middle and late growth stages. It should be noted that the crossing points of the two equations were found to be at the AETI of about 400. On the basis of the relationship between AETI and soil ammonium nitrogen shown in Fig. 3, it is assumed that the limiting factors are the ability of nitrogen absorption of the rice plants for the exponential part, and the rate of mineralization of soil organic

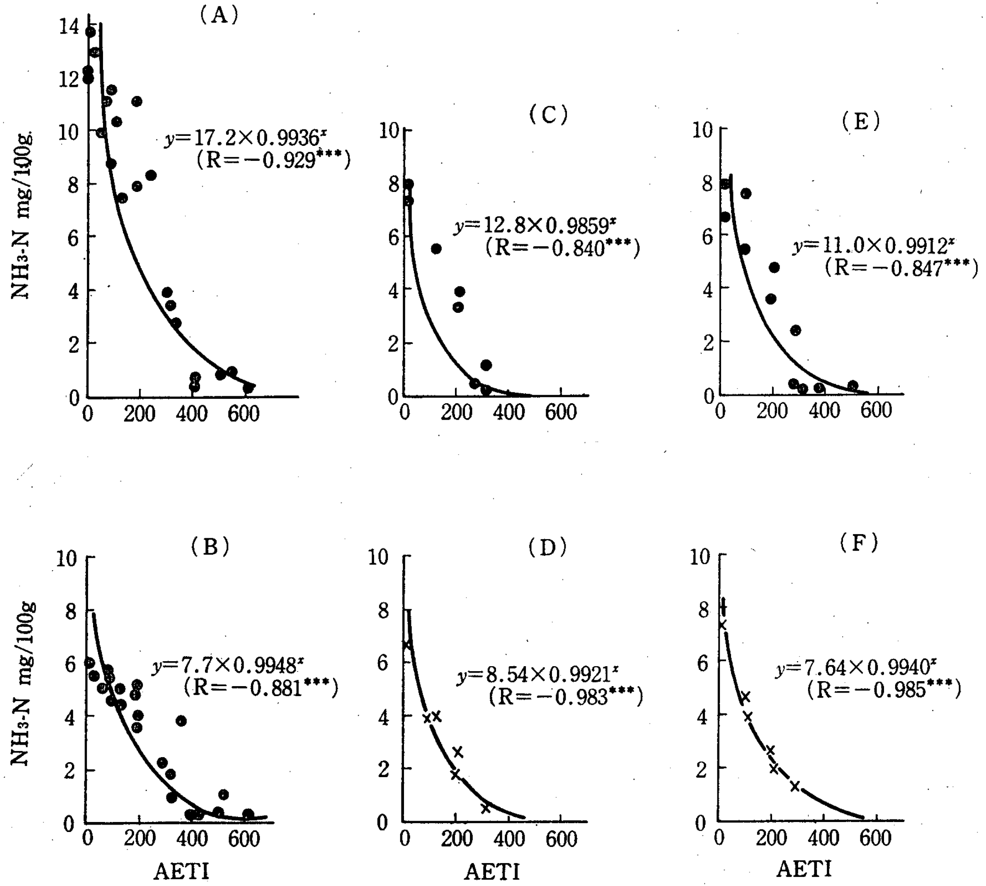

FIG. 3 Relationship between AETI and the amount of soil ammonium nitrogen
•——•; total of ammonium nitrogen derived from soil and fertilizer.
×——×; ;ammonium nitrogen derived from fertilizer.
(A); high rate of basal nitrogen, large seedling in Odawara field.
(B); standard rate of basal nitrogen, large seedling in Odawara field.
(C) and (D); standard rate of basal nitrogen, large seedling in Takadate field.
(E) and (F); standard rate of basal nitrogen, small seedling in Takadate field.

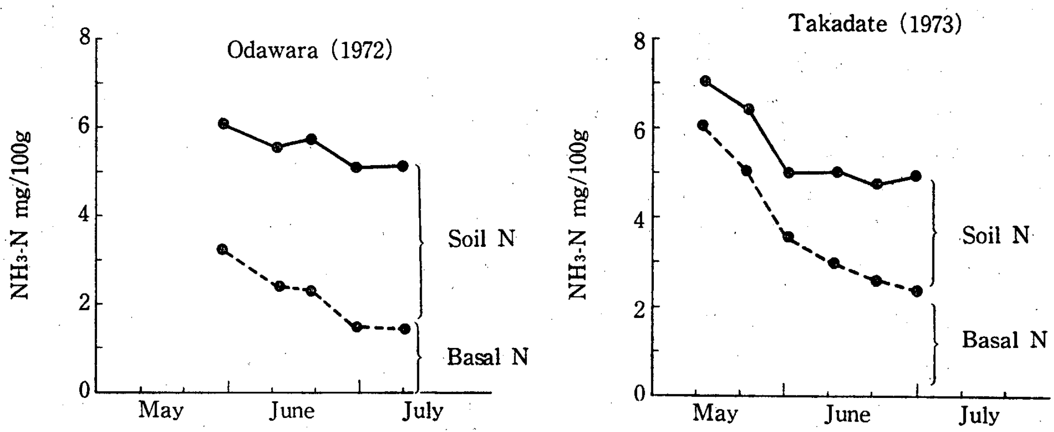

FIG. 4. The amounts of ammonium nitrogen derived from soil and basal nitrogen in the plots with the standard level of basal nitrogen (Rice seedlings were not transplanted.)

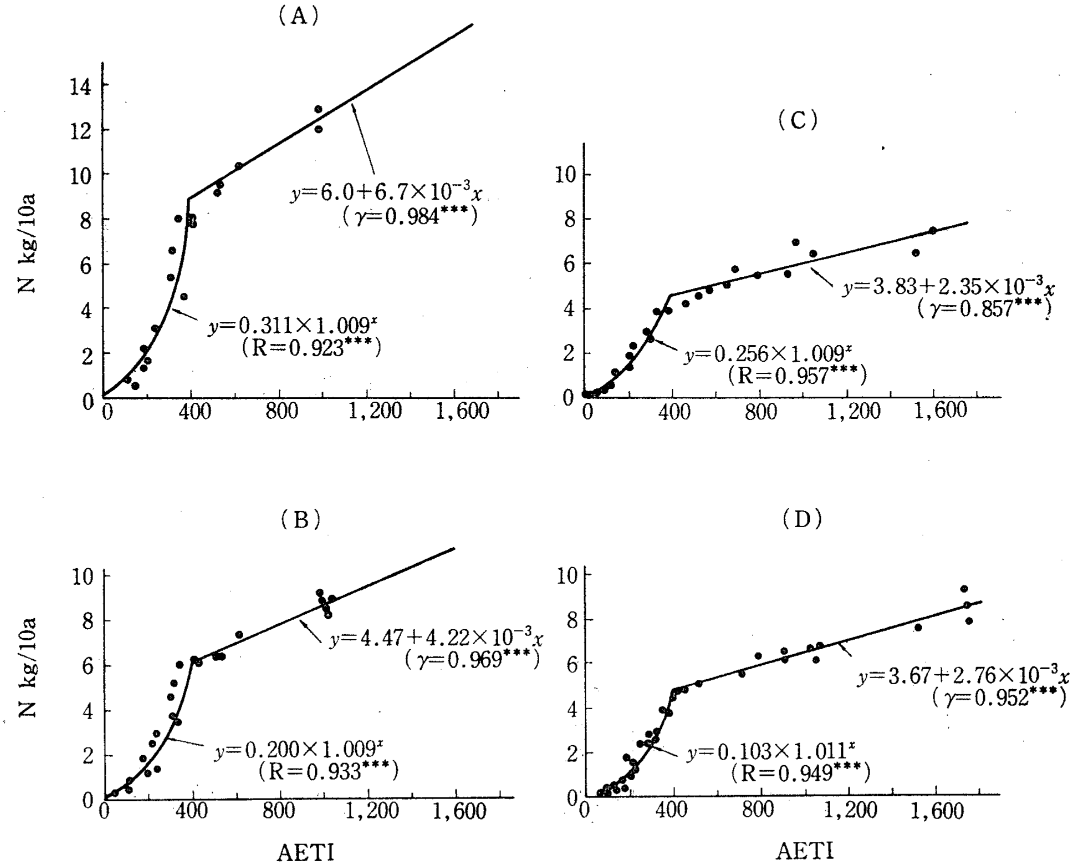

FIG. 5. Relationship between AETI and the amount of nitrogen absrobed by rice plants.
(A); high rate of basal nitrogen, large seedling in Odawara field.
(B); standard rate of basal nitrogen, large seedling in Odawara field.
(C); standard rate of basal nitrogen, large seedling in Takadate field.
(D); standard rate of basal nitrogen, small seedling in Takadate field.

nitrogen for the linear part.

Compared with the plot of standard level basal nitrogen in the Odawara field, the absorption speed of nitrogen by the rice plants in the plot of high level basal nitrogen in the same field, was greater not only in the early growth stage, but also in the middle and late growth stages. However, further investigation remains to be done to ascertain if the increase of basal nitrogen increases the absorption of soil nitrogen by the rice plants.

The absorption of nitrogen by the rice plants at the earlier growth stage in the Takadate field, is slightly greater in the large seedling plot than in the small seedling plot. However, at the middle and late growth stages, the speed of nitrogen absorption by the rice plants is almost the same in both plots.

Since the absorption of basal nitrogen by the rice plants finishes at the AETI of about 400, the mineralization of soil organic nitrogen is estimated by the slopes of linear equations. Comparison of plots with a standard level of basal nitrogen indicates that mineralization of soil organic nitrogen is considerably greater in

TABLE 4. *The Recovery of Basal Nitrogen in Rice Plants under Various Cultural Conditions*

Year (Field)	Basal N (kg/10a)	Transplanting date	Rice variety	Kind of seedling	Plant density (cm)	Shading	Rice straw (kg/10a)	Recovery at heading time (%)
1971 (Odawara)	7	May 6	Sasaminori	Large	30×12	—	—	27
	〃	May 24	〃	〃	〃	—	—	31
	〃	〃	〃	〃	30× 6	—	—	32
	〃	〃	〃	〃	30×12	June 10-25	—	29
	〃	June 10	〃	〃	〃	—	—	28
	15	May 6	Sasaminori	Large	30×12	—	—	28
	〃	May 24	〃	〃	〃	—	—	27
	〃	〃	〃	〃	30× 6	—	—	28
	〃	〃	〃	〃	30×12	June 10-25	—	27
	〃	June 10	〃	〃	〃	—	—	31
1972 (Odawara)	7	May 6	Sasaminori	Small	30×12	—	—	30
	〃	〃	〃	〃	〃	—	250	26
	〃	〃	〃	〃	〃	—	500	23
	〃	〃	〃	Large	〃	—	—	31
	〃	May 22	〃	〃	〃	—	—	29
	15	May 6	Sasaminori	Small	30×12	—	—	27
	〃	〃	〃	Large	〃	—	—	27
1973 (Takadate)	6	May 1	Sasanishiki	Small	30×12	—	—	43
	〃	〃	〃	〃	〃	—	500	27
	〃	May 10	〃	〃	〃	—	—	44
	〃	May 19	〃	〃	〃	—	—	43
	〃	〃	〃	Large	〃	—	—	45
	12	May 1	Sasanishiki	Small	30×12	—	—	39
1974 (Takadate)	7	May 7	Sasaminori	Small	30×12	—	—	40
	〃	〃	〃	〃	〃	—	500	29
	〃	May 25	〃	Large	〃	—	—	40
	〃	〃	〃	Small	〃	—	—	45
	〃	〃	〃	Large	30× 6	—	—	38
	〃	June 8	〃	〃	30×12	—	—	43
	15	May 25	Sasaminori	Large	30×12	—	—	34

Odawara soil than in Takadate soil.

Table 3 shows the recoveries of basal nitrogen in the rice plants under the various cultural conditions. All the plots including transplanting date, kinds of seedlings, plant density and shading, show almost the same recoveries in the standard dosage of basal nitrogen; 27–32 percent in Odawara field and 38–45 percent in Takadate field. On the other hand, application of rice straw decreased considerably the recoveries of basal nitrogen in both fields. Heavy applciation of basal nitrogen also decreased the recoveries of basal nitrogen slightly.

Acknowledgement

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