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Field Study on Translocation of Nitrogen and Its Contribution to the Growth of Wetland Rice at the Middle Growing Stage

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Summary

In order to show the translocation of N in field-grown rice and the contribution of the translocated-N to plants at the middle growth stage, a field study using ^{15}N was conducted on a fine-textured Gray Lowland Soil (Haplaquept). Three experimental plots such as low-N, standard-N and high-N were established and basal N labelled with ^{15}N was applied to these plots. ^{15}N contents of plant and soil samples were measured by an emission spectrography. The experimental results indicated that N was highly remobilizable in the plant and that the basal N absorbed by rice at the early growth stage was successively translocated to the new leaf-blades grown at the middle growth stage. The translocated-N comprised a great proportion of total N in these leaf-blades and showed marked contribution to their growth. Differences in the growth of rice plants at the middle growth stage definitely reflected the differences in the amounts of basal N taken up by rice at the early growth stage.

Nitrogen contributes to the growth and yield of agricutural plants to a great extent. However, the contribution shows a wide variation, reflecting various factors such as plant species, growth stage of plants, amount and time of nitrogen application, climate, soil conditions, etc. (1). Therefore, no other element requires such elaborate application techniques as nitrogen does.

Information concerning uptake and translocation of fertilizer and soil nitrogen by plants and contribution of the nitrogen to plant growth are basically important for increasing crop yields by efficient use of nitrogen. Tracer techniques based on the use of stable isotope ^{15}N are the most useful for these investigations under field conditions. However, field studies of effectiveness of such techniques on soil-plant relations have concentrated on uptake of fertilizer and soil nitrogen and recovery of fertilizer nitrogen in the plant (2, 3, 4, 5).

The objective of this paper is to show the tranlocation of N in rice plant and its contribution to plant growth. For this purpose, we conducted a field study using ^{15}N.

Materials and Methods

Properties of the Soil

The field experiment was conducted on a fine-textured Gray Lowland Soil (Haplaquepts) at Miyagi Agricultural Center, Takadate, Miyagi Prefecture Northeastern Japan. The Soil had 0.72% total C, 0.12% total N, and pH 5.6. It had a clay fraction dominated by smectite and 40.8 me/100 g of CEC.

Design of Field Experiment

As seen in Table 1 which shows the design of our field experiment for 1982, three experimental plots such as low-N, standard-N, and high-N were established. The basal fertilizers were applied to the whole plowed layer (0-12 cm) several days before transplantation of rice seedlings. The topdressed N was applied over the surface of the paddy soil at the young ear formation stage (July 21).

Each experimental plot had microplots (0.9 m × 1.5 m) surrounded by plastic plates in order to prevent labelled N from moving out of the microplots through the flood water. Ammonium sulfate with 3.02 atom% of ^{15}N was applied to these microplots.

The seedlings of rice (*Oryza sativa L.* cv. Sasanishiki) were transplanted at the third leaf age (May 10). The spacing was 30 cm × 15 cm and number of seedlings per hill was 5.

Analysis

Soil was sampled by obtaining ten soil cores (7 cm diameter, 12 cm depth) every week after transplantation. Rice plants of 30 hills were sampled for each experimental plot at intervals of about a week until the end of June, and then at intervals of about 10 days. These intervals were necessary for the leaf emergence at early and middle growth stage, respectively.

TABLE 1. *Design of field experiment*

Plot	Basal application (kg/ha)			Topdressing (kg/ha)
	N	P_2O_5	K_2O	N
Low-N	20	100	100	20
Standard-N	40	100	100	20
High-N	100	100	100	20

Date of transplantation	May 10, 1982
Rice cultiver	Sasanishiki (*Oryza sativa.* L.)
Seedling age	3rd leaf age
Spacing	30 cm × 15 cm
Number of seedlings per hill	5

Soil samples were extracted with M KCl solution and the extracted solutions were analyzed for ammonium N by steam distillation method (6).

For the analyses, 30 plants were taken from each experimental plot at each sampling time and were separated into two parts; all the tops, except the new leaf-blades, and the new leaf-blades. The total N of each plant sample was determined by the distillation method after the Kjeldahl digestion (6). ^{15}N

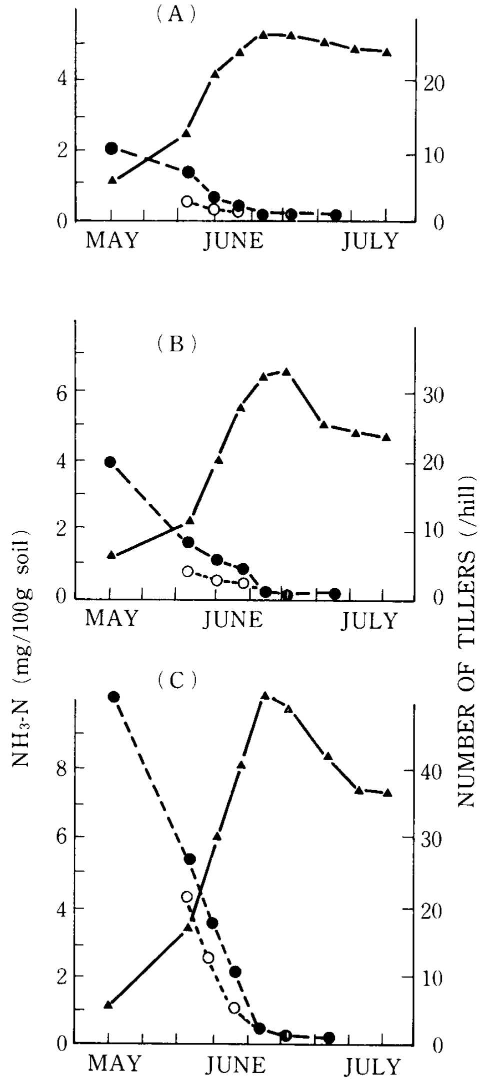

Fig. 1. Level of ammonium N in the soil and number of tillers of rice in each experimental plot at the early and middle growth stage.

(A) = low-N plot
(B) = standard-N plot
(C) = high-N plot
▲——▲ = number of tillers
●------● = total ammonium N
○------○ = ammonium N from basal N

TABLE 2. *Dry matter yield, N content,*

Sampling date	Dry weight		N content		
	A# (mg/hill)	B## (g/hill)	A (%)	B	
					Standard-N plot
June 3 $\bar{x}$		0.68		3.99	
S.D.		0.17		0.342	
June 10 $\bar{x}$	267	2.2	3.67	2.44	
S.D.	98	0.50	0.438	0.269	
June 17 $\bar{x}$	545	3.7	3.00	1.95	
S.D.	169	0.739	0.295	0.230	
July 1 $\bar{x}$	990	7.4	2.03	1.29	
S.D.	294	1.55	0.179	0.142	
July 12 $\bar{x}$	1169	10.3	2.21	1.20	
S.D.	272	2.02	0.111	0.080	
July 21 $\bar{x}$	981	12.0	1.92	1.10	
S.D.	145	1.67	0.192	0.104	
July 30 $\bar{x}$	916	14.7	2.58	1.37	
S.D.	273	4.09	0.300	0.205	
					Low-N plot
July 12 $\bar{x}$	939	7.9	2.24	1.25	
S.D.	168	1.25	0.161	0.083	
July 21 $\bar{x}$	937	10.0	2.05	1.17	
S.D.	235	2.04	0.143	0.096	
July 30 $\bar{x}$	825	12.7	2.18	1.27	
S.D.	210	2.67	0.494	0.314	
					Higi-N plot
July 12 $\bar{x}$	2300	17.0	2.33	1.43	
S.D.	575	3.77	0.196	0.116	
July 21 $\bar{x}$	1936	21.6	2.09	1.20	
S.D.	298	2.54	0.136	0.091	
July 30 $\bar{x}$	1429	25.6	2.16	1.20	
S.D.	342	5.28	0.280	0.193	

New leaf-blades
Whole plant

contents of plant and soil samples were measured by emission spectrography with a JASCO ^{15}N-analyzer (NIA-1) (7).

Results and Discussion

Analytical data of ammonium N in the soil is shown in Fig. 1. The levels of total ammonium N responded to the basal N levels at the transplanting time and then indicated a rapid decline. It was noted that ammonium N largely disappeared at the time of maximum number of tillers or at the end of June in all the experimental plots.

The ammonium N derived from basal fertilizer N showed a trend similar to *and N uptake of rice plant*

N uptake		Ratio of basal N to total N		Basal N uptake		Soil N uptake	
A	B	A	B	A	B	A	B
(mg/hill)		(mg/hill)		(mg/hill)		(mg/hill)	
	27.09		0.545		14.81		12.28
	6.69		0.058		4.07		3.29
9.75	52.73	0.495	0.525	4.95	28.47	4.80	24.26
3.52	13.51	0.097	0.091	2.26	11.48	1.78	5.18
16.60	72.20	0.382	0.416	6.93	31.47	9.67	40.74
6.22	20.27	0.122	0.113	4.89	16.83	2.03	7.95
20.16	98.64	0.288	0.327	6.20	33.95	13.96	64.70
6.75	25.27	0.093	0.089	3.73	16.59	3.58	11.27
25.88	123.74	0.240	0.274	6.38	34.66	19.50	89.09
6.57	26.77	0.070	0.069	2.98	13.53	4.48	17.40
18.77	132.18	0.231	0.261	4.30	34.11	14.47	98.06
2.89	17.57	0.050	0.050	1.07	5.94	2.64	17.32
23.41	201.23	0.133	0.177	3.17	36.88	20.24	164.35
6.71	59.98	0.060	0.064	1.97	23.13	5.77	45.07
20.98	98.03	0.143	0.169	3.03	16.83	17.96	81.20
3.94	14.50	0.038	0.041	1.00	5.53	3.26	10.59
19.35	116.24	0.139	0.147	2.72	17.53	16.64	98.71
5.51	23.42	0.038	0.040	1.12	7.32	4.63	18.00
17.89	161.60	0.085	0.117	1.47	18.23	16.42	143.37
5.80	55.74	0.048	0.051	0.93	8.36	5.64	53.26
53.51	244.47	0.567	0.576	31.26	144.96	22.25	99.50
14.64	64.66	0.086	0.083	12.63	57.07	3.58	14.90
40.40	259.01	0.503	0.531	20.42	138.58	19.99	120.42
6.92	41.22	0.059	0.065	4.54	31.25	3.83	20.06
30.74	307.80	0.373	0.425	11.51	131.02	19.23	176.78
7.83	81.93	0.099	0.076	4.21	41.06	5.65	53.76

the total ammonium N. However, the ratios of ammonium N from basal N to total ammonium N decreased with the lapse of time, indicating that ammonium N from basal N was diluted with ammonium N from soil organic N.

As seen in Fig. 1, the number of tillers of rice per hill roughly respended to the levels of basal N. However, the time of maximum number of tillers was observed to be almost the same for all the experimental plots. As Ando et al (8) stated, we considered that the time of maximum number of tillers is not primarily determined by the growth stage, but by a limitation of N supply to rice plants necessary to continue their tillering.

Data on dry matter production and N uptake of rice is presented in Table 2.

Both N uptake by rice and dry weights of the whole plant responded to the basal N levels.

In accord with time of disappearance of soil ammonia, basal N uptake by rice was virtually finished at the time of maximum number of tillers or 40 days after transplantation. This observation is coincident with the finding by Ando et al (8) and Katsumi (9). Therefore, N taken up by rice consisted wholly of soil N at the middle growth stage before N topdressing. Though the ratios of basal N to total N in the plant decreased with the advance of plant growth, these ratios definitely responded to the basal N rates.

Thanslocation of Nitrogen in Rice Plant

We studied translocation of N in the plants at the middle growth stage through two approaches:

1) Comparing the ratios of basal N to the total N in all the aerial parts of plant with the corresponding ratios in the new leaf-blades at each leaf age, and

2) determining the origins of N in the new leaf-blades.

The term "new leaf-blades" was used specifically in this paper to denote the top leaf-blades of main rice stems and those of tillers which emerged at the same time. Since basal N uptake by rice was finished before the completion of expansion of leaves, the new leaf-blades grown at the 12th to 14th leaf (flag leaf) age were the most suitable for the study of the N translocation.

Fig. 2 shows the ratios of basal N to the total N (basal N + soil N, or basal N + soil N + topdressed N) for the new leaf-blades and for the whole plant at each leaf

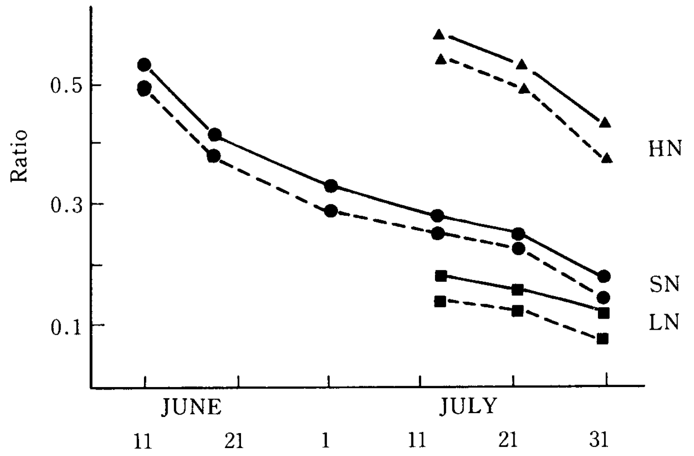

FIG. 2. Ratios of basal N to total N in the new leaf-blades and in the whole plant in each experimental plot at various sampling times.
HN = high-N plot
SN = standard-N plot
LN = low-N plot
Full line = whole plant
Dotted line = new leaf-blades

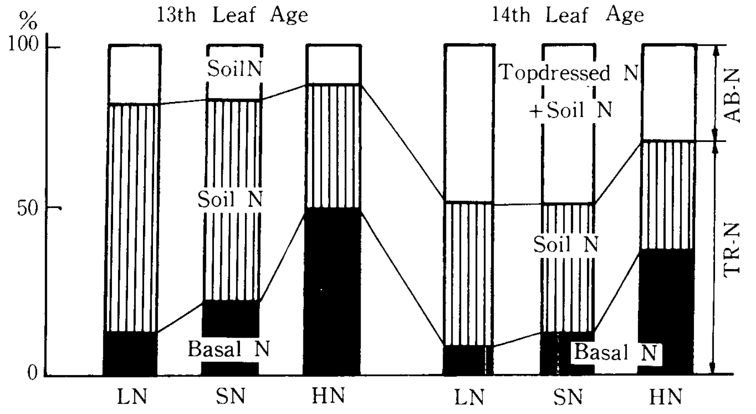

FIG. 3. Origins of N in the new leaf-blades of rice at the 13th and the 14th leaf age.
HN = high-N plot
SN = standard-N plot
LN = low-N plot
TR-N = translocated-N
AB-N = absorbed-N

age. These two kinds of ratios definitely responded to increasing rates of basal N fertilization and decreased gradually with the advance of plant growth.

The ratios for the new leaf-blades were smaller than the ratios for the whole plant in all the experimental plots. However, it should be noted that the differences between the two ratios are not large even after the completion of basal N uptake by the plant.

From the field study described above, it is obvious that N is very remobilizable in rice. This fact is coincident with the results of previous works using ^{15}N (10, 11, 12, 13, 14, 15, 16).

N in the new leaf-blades can be divided into two groups on the basis of its origins as described below. One is "absorbed-N" which is freshly assimilated and is incorporated into the new leaf-blades during their growing period. The other is "translocated-N" which pre-existed in the plant before the new leaf-blades start to grow and is remobilized to the new leaf-blades from the other parts of the plant during their growing period.

Fig. 3 shows the sources of N in the new leaf-blades at the 13th and 14th leaf age. All the basal N contained in these leaf-blades was translocated-N because basal N uptake by rice was complete at the 9th to 10th leaf age. Based on this fact, we obtained total translocated-N in the new leaf-blades as *n*th leaf age by dividing basal N in the new leaf-blades at the *n*th leaf age by ratios of basal N to total N in the whole plant at the (*n*-1)th leaf age. Translocated soil N was obtained by subtracting the basal N (translocated-N) from the total translocated-N in the new leaf-blades.

It should be noted that more than 80% of total N in the new leaf-blades was translocated-N which consisted mainly of soil N in the low-N and standard-N plots but of basal N in the high-N plot.

Less than 20% of total N in the new leaf-blades was absorbed-N at the 13th leaf age. Since uptake of basal N by rice was finished at the 9th to 10th leaf age, it is obvious that this absorbed-N originated from soil organic N.

Topdressing of N influenced significantly the N composition of the new leaf-blades at the 14th leaf age. As seen in Fig. 3, enhance N uptake by rice decreased the ratios of translocated-N to total N in the new leaf-blades to a considerable extent. However, the translocated-N still comprised about one half or more of total N and the ratios of translocated-basal N showed a definite response to the rates of basal N fertilization.

The results of our field study described above indicated that N is very remobilizable in the plant and that a large portion of N in the new leaf-blades is translocated-N.

Contribution of Translocated-N to the Growth of the New Leaf-blades at the Middle Growing Stage

Of the various measures such as plant height, number of tillers, leaf area, dry weight, etc., dry weight shows the highest correlation to the N uptake by rice at the middle growth stage. Therefore, we studied the contribution of translocated-N to rice growth by determining the relationships between dry matter yields and amounts of translocated-N of the new leaf-blades at the 12th and 13th leaf age.

Fig. 4 and regression equations described below show very close linear correla-

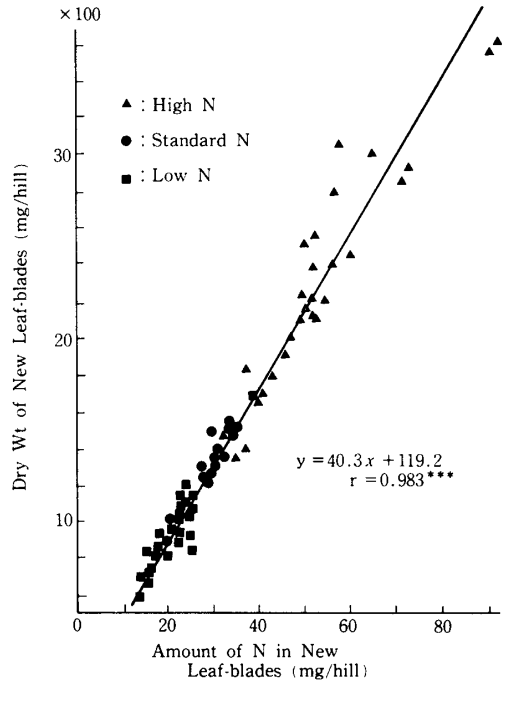

FIG. 4. Relationship between amount of N and dry matter yield of new leaf-blades at the 12th leaf age.

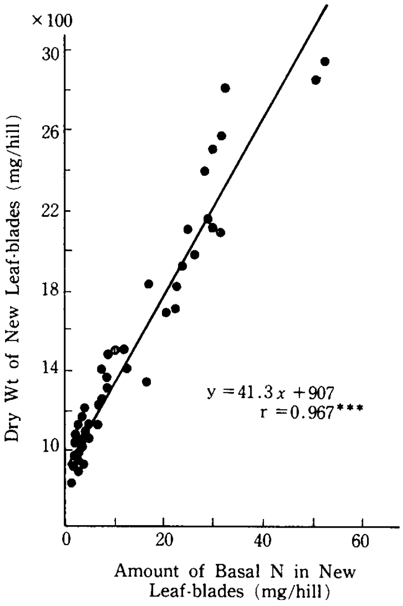

FIG. 5. Relationship between amount of basal N and dry matter yield of new leaf-blades at the 12th leaf age.

tions between the amounts of total N (x mg/hill) and dry matter yields of the new leaf-blades (Y mg/hill).

$Y=40.3x+119.2$ (n=90, r=0.983***) for the 12th leaf age

and $Y=44.7x+115.3$ (n=90, r=0.985***) for the 13th leaf age

Since a large proportion of N in these new leaf-blades are translocated-N as seen in Fig. 3, it is certain that this N contributed to a great extent to the growth of the new leaf-blades.

In order to determine more exactly the contribution of translocated-N to the rice growth, we studied the relationships between the amounts of basal N, all of which is translocated-N, and dry matter yields of the new leaf-blades at the 12th and 13th leaf age.

For this purpose, we selected plant samples whose amounts of soil N in the new leaf-blades showed the mean ($\bar{x}$) or values close to the mean ($\bar{x}\pm t_{0.5}\frac{s}{\sqrt{n}}$). The values of $\bar{x}\pm t_{0.5}\frac{s}{\sqrt{n}}$ were 19.90±2.81 (mg/hill) at the 12th leaf age and 17.03±2.96 (mg/hill) at the 13th leaf age, respectively.

There were close positive correlations between the amounts of basal N (x mg/hill) and dry matter yield (Y mg/hill) of the new leaf-blades as shown by the following equations and in Fig. 5.

$Y=41.3x+907$ (n=49, r=0.967***) for the 12th leaf age

and $Y=50.5x+814$ (n=44, r=0.964***) for the 13th leaf age

The results presented evidence that the basal N taken up by rice at the early growth stage made the important contribution to the growth of leaf-blades at the middle growth stage through translocation. Notable differences in the dry matter yields of new leaf-blades among the three experimental plots were due to the differences in the amounts of basal N absorbed by rice at the early growth stage.

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