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Single Application of Controlled Availability Fertilizer to Nursery Boxes in Non-Tillage Rice Culture

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Abstract

Single application of a controlled availability fertilizer (CAF; sigmoid type) to nursery boxes was investigated for non-tillage rice culture. The soil used for the study was a Gley soil with poor drainage. The cumulative release rate of total N from the CAF was 2.8% in 34 days at the nursery stage without artificial heating. The CAF application increased the number of tillers, when compared to the conventional compound fertilizer (CF), even through the total amount of nitrogen applied with the CAF was only 50-60% of that with the CF. The uptake of nitrogen by rice plants treated with the CAF was higher than that with the CF. The recovery of the CAF N was as high as 79% at the maturing stage. The roots of rice plants with the CAF extended deeper into the subsoil. The CAF applications increased the yield of rice by 10% compared with the CF applications.

Discipline: Soils, fertilizers and plant nutrition
Additional key words: recovery rate, direct contact dressing, ^{15}N tracer

Introduction

In recent years, Japanese agriculture has been facing serious problems including supply–demand imbalance of rice, advanced average age of farmers and a small number of successors in the farm. To continue rice culture in future (1) it will be important to reduce the labor and production cost and (2) to increase the productivity.

Non-tillage rice culture which eliminates conventional plowing and puddling is expected to increase labor efficiency. Farmers had already practiced non-tillage transplanting by hand on a small-scale[2,12]. With the development of efficient non-tillage transplanters, farmers are now beginning to implement this type of culture in large-scale fields. We have evaluated methods of fertilizer application in the non-tillage rice culture since 1990.

In non-tillage rice culture, farmers have tended to use an excessive amount of fertilizer for basal dressing and top dressing in order to obtain an appropriate number of ears. This is because the amount of available nitrogen from non-tillage soil is smaller than that from puddled soil, and also, the recovery of nitrogen from fertilizer with basal application in the surface layer is very low in non-tillage rice culture. Therefore, improved fertilizer N recovery is essential in this culture system.

In recent years, new controlled availability fertilizers (CAF) have been developed in Japan[1] using a coating technique. The N of the CAF is released slowly at rates corresponding to the soil temperature during the crop growing stages. The recovery of CAF N by rice plants was higher than that of compound fertilizers (CF)[3,13]. By using CAF rice plants grew well after a single basal application[13].

A new type of CAF, where N release is delayed for a specified number of days and then increases rapidly after the lag period, has been developed in Japan. This CAF is designated as LPS because the release pattern of N follows a sigmoid-like curve. The LPS can be mixed in nursery bed soil before rice seeding without causing any salt injury in the germinated plants.

It was reported that LPS applied at the time of transplanting to come into contact with seedling roots, effectively supplied a sufficient amount of N throughout the growing stages and eliminated further top dressing[9]. We evaluated the effect of a single application of CAF to nursery boxes for non-tillage rice culture.

Experiments

The experiments were conducted in the paddy fields at Akita Experimental Station Farm in 1991. The soil is a fine-textured strong-gley soil with poor drainage.

1) Properties of controlled availability fertilizer

The CAF used in the experiment is a sigmoid-type slow release N fertilizer (40% N). The release of N is almost nil for about 30 days, and reaches a value of about 80% of the total content in water at 25°C within 70 days after the lag period.

2) Method of single application in nursery boxes

CAF at a rate of 400 g or 600 g, equivalent to 160 g or 240 g of N, per nursery box (30 × 60 × 3 cm), respectively and CF (0.5 g N, 2.4 g P_2O_5, 1.5 g K_2O per box) were used by mixing with nursery bed soil (3,100 g) 10 days before rice seeding in the CAF plot. In the CF plot, CF (1.5 g N, 2.4 g P_2O_5, 1.5 g K_2O per box) was used by mixing with nursery bed soil. The rate of seeding was 100 g per box. This experiment required 260 nursery boxes ha^{-1}. After seeding, the nursery boxes were placed in a vinyl plastic greenhouse without artificial heating. The rate of fertilizer application is shown in Table 1. The application of CAF 400 g and 600 g was equivalent to a basal dressing of 41 kg N ha^{-1} and 62 kg N ha^{-1}, respectively. In the CF plot, basal dressing consisted of 40 kg N ha^{-1} as CF in the surface and top dressing of 20 kg N ha^{-1} each at the tillering stage, the panicle formation stage, and the reduction division stage with ammonium sulfate. During the 34-day period of raising of seedlings, management of water and temperature was similar to the conventional method, but top dressing was not applied in the CAF plot. In the CF plot, top dressing of 1 g N each was applied 3 times by using an ammonium sulfate solution. After 34 days (Plate 1), the seedlings were transplanted using a non-tillage transplanter (Mitsubishi Co., Japan) with driving disks to make ditches (Plate 2).

3) Release of controlled availability fertilizer N

Fig. 1 shows the cumulative N release from the CAF with time during the raising of seedlings and throughout the growing period at the soil depth of 5 cm. The cumulative soil temperature in the nursery boxes during 34 days in the raising period was 615°C. The cumulative N release from the CAF was

Table 1. Experimental design (Variety: Akitakomachi)

Fertilizer[a]	Basal dressing (kg ha^{-1})			Top dressing (N kg ha^{-1})		
	N	P_2O_5	K_2O	Tillering stage	Panicle formation stage	Reduction division stage
CF	40	80	20	20	20	20
CAF 400 g	41[b]	0	0	0	0	0
CAF 600 g	62[b]	0	0	0	0	0

a): CF: Compound fertilizer, CAF: Controlled availability fertilizer.
b): Rate of nitrogen by carrying over into fields from nursery box.

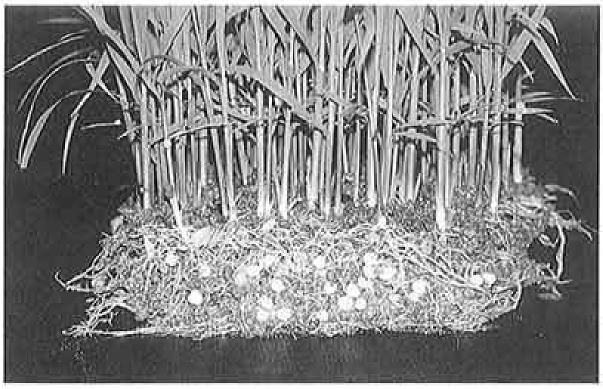

Plate 1. CAF in nursery box after 34 days from seeding

Plate 2. The non-tillage transplanter in operation

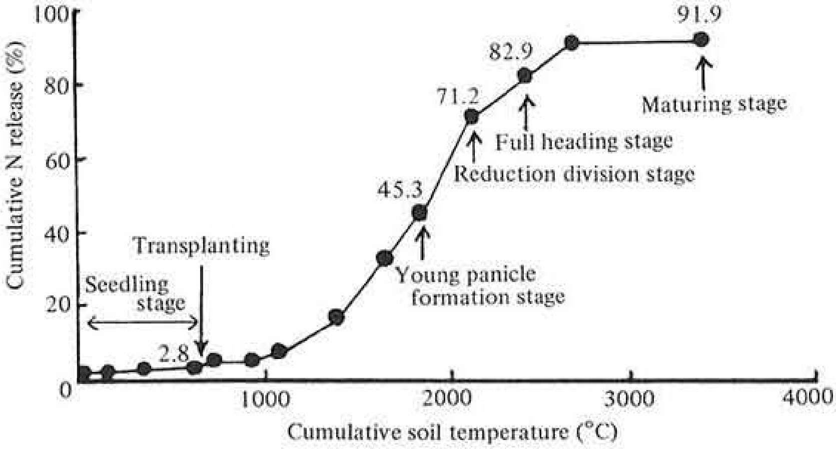

Fig. 1. Cumulative N release from CAF with cumulative soil temperature (1992)

2.8% of the total during this period. After transplanting, the rate of N release from the CAF increased during the tillering stage (cumulative soil temperature of 1,000°C) and the reduction division stage. After this stage, the nitrogen release was very slow until the cumulative temperature reached about 3,500°C.

The cumulative N release from the CAF amounted to about 80% of the total N content at the cumulative temperature of 2,500°C, and 92% at the maturing stage at about 3,500°C.

4) Properties of rice seedlings

Table 2 shows the properties of the rice seedlings at the transplanting stage. Dry weight and N concentration of the seedlings in the CAF 600 g plot were higher than those in the CF plot. Dry weight and N concentration in the CAF 400 g plot, however, were lower than those in the CF plot, because the rate of CF N, 0.5 g, mixed with the CAF was low. It is considered that the suitable rate of the CF N per box is 1.0 g.

5) Growth and N uptake

Fig. 2 shows the changes in the number of tillers during the growing season. The tiller number increased slightly faster in the CAF 400 g plot than in the CF plot. The number of tillers increased much faster in the CAF 600 g plot than in the CF plot throughout the growing period. The number of ears was 376 m^{-2} in the CAF 400 g plot and 466 m^{-2} in the CAF 600 g plot, values approximately 10 and 37% higher than that in the CF plot, respectively.

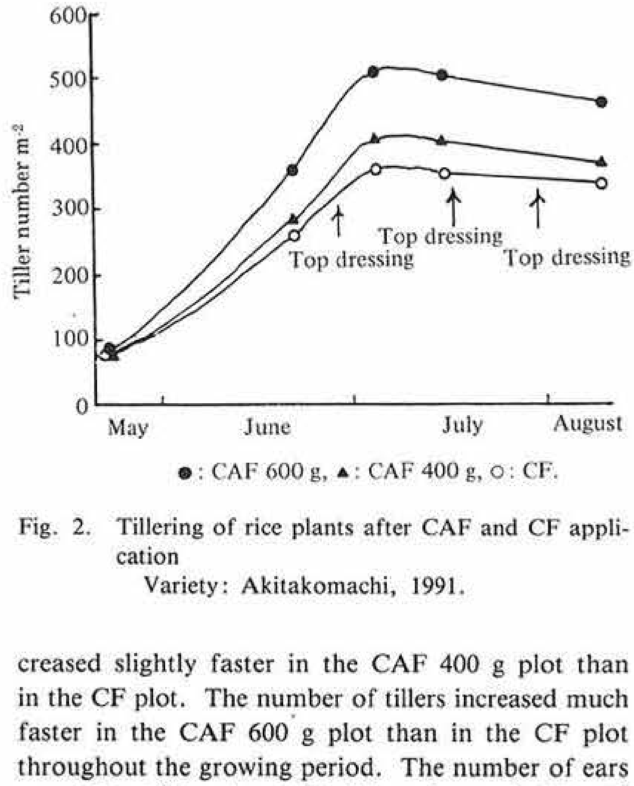

Fig. 2. Tillering of rice plants after CAF and CF application
Variety: Akitakomachi, 1991.

Table 2. Properties of the seedlings (1991)

Fertilizer[a)]	Plant age (leaf number)	Plant length (cm)	Dry weight (g/100 plants)	Nutrient concentration (%)		
				N	P_2O_5	K_2O
CF	3.9	11.8	2.31	4.87	1.40	2.72
CAF 400 g	3.9	10.2	1.98	3.30	1.19	2.17
CAF 600 g	3.8	11.8	2.42	5.51	1.39	2.91

a): CF; Compound fertilizer, CAF; Controlled availability fertilizer.

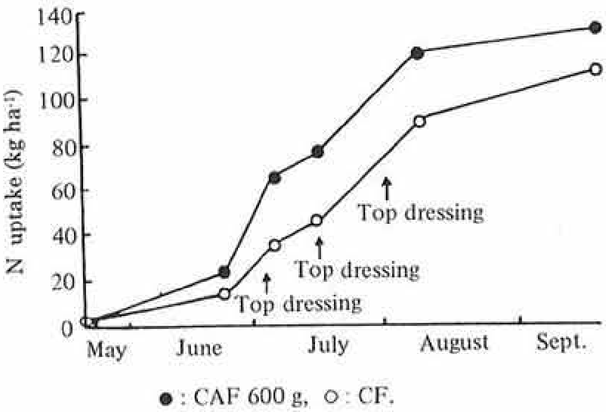

Fig. 3. N uptake by non-tillage transplanted rice in CAF and CF application
Variety: Akitakomachi, 1991.

Fig. 3 shows the increase of the N uptake by rice plants. The N uptake increased faster in the CAF 600 g plot than in the CF plot throughout the growing period. The N uptake increased rapidly from the tillering stage untill the reduction division stage, during the period when N release from the CAF was rapid.

Amount of N uptake in the CAF 600 g plot at the maturing stage was 134 kg ha^{-1}, 17% higher than that in the CF plot (114 kg ha^{-1}).

6) Uptake of N from controlled availability fertilizer and soil

Fig. 4 shows the increase of the uptake N from the CAF and the soil in the CAF 600 g plot. After transplanting, the recovery of the CAF N was low, 1.4% in early June and 9% in late June. At the full heading stage, the recovery was 67% and it increased gradually thereafter. The recovery of the CAF N was 79% at the maturing stage.

The recovery based on the amount of N released reached a plateau around 83% in July. At the maturing stage, the amount of N uptake by rice plants from the CAF was 49 kg ha^{-1} and that from the soil was 85 kg ha^{-1}, accounting for 37 and 63% of the total N uptake, respectively.

7) Extension of roots

Fig. 5 shows the dry weight of roots at different soil depths in the CAF 600 g plot at the full heading stage. A large number of roots were distributed in the surface layer within a 5 cm depth, accounting for 61% of the total root dry weight. The rate of roots below a 10 cm depth was 14% of the total roots. The roots in the CAF plot reached even the subsoil and were distributed in all the soil layers.

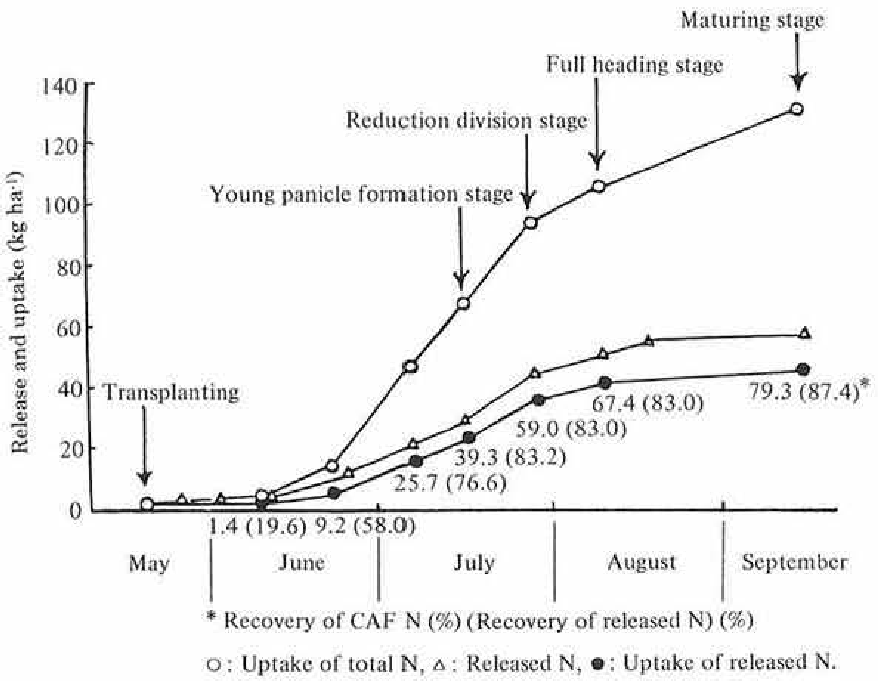

Fig. 4. Rate of release of CAF N, uptake of released N and total N by rice plants
CAF 600 g. Variety: Akitakomachi, 1992.

Table 3. Effect of fertilizer application on rice yield (1991)

Fertilizer[a)]	Culm length (cm)	Panicle number (m^{-2})	Yield (kg ha^{-1})		Number of rice grains ($\times 10^3 m^{-2}$)	Percentage of ripened grains (%)	Thousand-kernel weight (g)
			Brown rice	Index number			
CF	80	341	5,760	(100)	28.5	92.4	21.8
CAF 400 g	82	376	6,040	105	32.2	90.3	21.1
CAF 600 g	85	466	6,540	113	35.0	90.0	20.8

a): CF; Compound fertilizer, CAF; Controlled availability fertilizer.

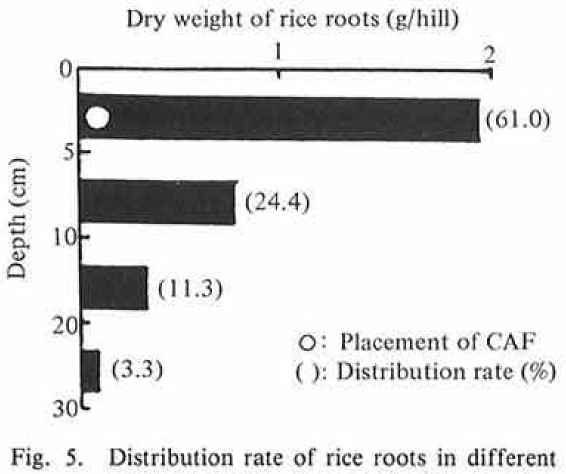

Fig. 5. Distribution rate of rice roots in different soil horizons in single application to nursery box
CAF 600 g.
Variety: Akitakomachi, 1992.

8) Yield and yield components

Brown rice yields and yield components are listed in Table 3. Comparison of the yield components showed that the higher brown rice yields in the CAF plots were mainly due to the larger number of ears. The brown rice yields were 6,040 and 6,540 kg ha^{-1} in the CAF 400 g plot and CAF 600 g plot, respectively, values which were 5 and 13% higher, respectively than that in the CF plot (5,760 kg ha^{-1}). Single application of the CAF to the nursery boxes for the non-tillage rice culture was beneficial.

Discussion

Advantages of the non-tillage rice culture are as follows: (1) reduction of production cost and labor, (2) improvement of water percolation and tractor trafficability in paddy fields, (3) protection of upland crops succeeding rice culture against wet injury, (4) decrease of the amount of methane generation in the plow layer, and (5) contribution to the control of water pollution[4,5]. Effectiveness of non-tillage rice culture is especially significant as a method of soil management in Gley soil with poor drainage to promote the drying of paddy soil during the rice growing stage, and to facilitate the conversion to upland crop cultivation. Previous studies showed that nitrogen was a limiting factor of rice growth in the non-tillage direct-seeding rice culture, because the amount of available nitrogen was smaller in the non-tillage soil than in the puddled soil. The recovery of fertilizer applied in the surface layer was very low in the non-tillage rice culture[7]. Similar phenomena were observed in the CF plot in the present experiments. The low N uptake from the soil with non-tillage transplanted rice was caused by the slow reduction of soil and low level of mineralized nitrogen from the soil. It is considered that a low recovery of fertilizer occurred in the non-tillage rice culture because fertilizer N applied at the surface was rapidly nitrified and denitrified. Growth is satisfactory even in the case of nitrogen deficiency in the southwestern region of Japan where the soil nitrogen supply is too abundant in the initial stage of growth due to the high temperature[8]. In the cool Tohoku region, however, the promotion of initial growth is highly effective in increasing the number of panicles. Therefore, farmers carry out transplanting in non-tillage fields usually with the application of highly soluble N fertilizers in order to increase rapidly the number of rice tillers during the early growth stage. Efficient uptake of fertilizer is required for such non-tillage rice culture.

It was reported that the recovery of the CF N applied in the surface layer was very low (9%)[4]. The recovery of the CF N in the Tohoku region was about 30% of the total amount of CF N applied to the whole plow layer[11]. The recovery of the CF N was about 40% with band dressing[10]. It has also been reported that the recovery of the CAF N applied to the whole plow layer was 60%[3,13].

In contrast, the recovery of the CAF N applied to nursery boxes without salt injury of seedlings increased to a value of 79% at the maturing stage.

It was reported that the extension of rice roots

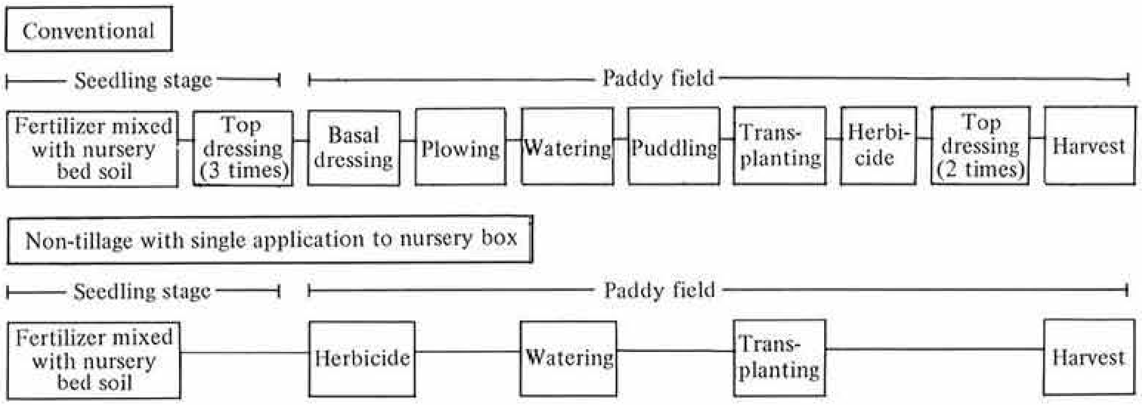

Fig. 6. Comparison of operations required in conventional cultivation and non-tillage cultivation with single application of fertilizer to nursery box

was markedly influenced by direct contact application of the CF[6]. Our experiments, however, showed that direct contact application of the CAF did not injure seedlings and roots.

It was reported that the appropriate rate of N application in nursery boxes with the CAF was 320 g per box in Andosol paddy fields[9]. Our experiments showed that the suitable rate of N with the CAF was 200–240 g per box which was equivalent to a basal dressing of N of 50–60 kg ha^{-1}. Suitable rate of fertilizer N carried over into paddy fields with seedlings was 40–50% lower than the sum of the amount of basal dressing and top dressing nitrogen with the CF. Therefore, non-tillage rice culture with a single application of N to nursery boxes with the CAF could save the labor of fertilizer application (Fig. 6). The system is considered to be effective for low-cost rice culture and high productivity.

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