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REVIEW

Utilization Advantages of Controlled Release Nitrogen Fertilizer on Paddy Rice Cultivation

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Abstract

Labor-saving for fertilization has been strongly desired due to the shortage in labor and increasing scale of farming for rice cultivation. In order to clear these problems, the effect of application of controlled release nitrogen fertilizer (CRNF) on the different styles of paddy rice cultivation was investigated in southwestern Japan. Yield of transplanted rice grown by a single basal application of fertilizer consisting of 30% to 70% of sigmoid CRNF-100 was approximately equal to that grown by split application of ammonium sulfate under the same amount of nitrogen applied. In direct sowing cultivation under dry and flooded condition, rice yield was elevated by using nitrogen fertilizer consisting of 85% to 100% of CRNF. Approximately 30% of nitrogen applied was reduced in a single basal application with fertilizer consisting of 100% of CRNF nitrogen compared with that in split application with ammonium sulfate. Labor for nitrogen topdressing was completely saved by utilizing a single basal application with CRNF. The utilization of nitrogen fertilizer consisting of CRNF was also thought to be preservative to the environment.

Discipline: Crop production
Additional key words: transplanting cultivation, direct sowing cultivation, single basal application

Introduction

Many papers have been reported concerning fertilization of transplanting rice cultivation. Of nutrients, intensive nitrogen fertilization, which is most important for plant growth, has been investigated using conventional nitrogen fertilizer such as ammonium sulfate, and the split application method of nitrogen fertilizer has been elaborately established in transplanting cultivation.

Recently, labor-saving for fertilization has been strongly desired due to the shortage in labor and the expansion in the scale of rice farming[1,3] in Japan. Many researchers are actively investigating labor-saving fertilization methods using controlled release nitrogen fertilizer (abbreviated as CRNF hereafter) as it is one of the useful methods.

As it is able to fit the nitrogen demand of rice, efficient nitrogen absorption and a decrease in the amount of applied nitrogen are attained by using CRNF. Furthermore, through reducing nitrogen loss from paddy fields by using CRNF rather than using conventional nitrogen fertilizer, the amount of nitrogen loss to the environment may be decreased.

Since environmental conservation has become an important problem, the development of environmentally conscious fertilization using CRNF is very important. As nitrogen release from CRNF is strongly affected by soil temperature, there are possibilities of a delay in the time of nitrogen release and incompatibility with rice growth. In such case, utilization of CRNF may cause a decrease in yield and quality. Both a decrease in nitrogen loss to the environment and labor-saving application techniques should be established, through utilizing in full understanding of the nitrogen release characteristics of coated fertilizer. Therefore, advantages of CRNF utilization in different rice cultivation methods including transplanting and direct sowing are introduced in this paper.

Materials and Methods

1. Effect of application of mixed fertilizer containing ammonium sulfate and coated urea on transplanted rice

The experiments were carried out in a field of gray lowland soil at Kyushu National Agricultural Experiment

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Station (KNAES), Chikugo, Fukuoka Pref., Japan from 1994 to 1996. Seedlings of "Hinohikari" at the 3 leaf-stage raised in the Minoru type of nursery box were transplanted with spacing of 30 × 20 cm. Plots of no nitrogen application, split application of ammonium sulfate, and a single basal application of coated urea mixture were set up with 9 gN m^{-2}. The last plot was divided into 3 subplots using coated urea-SS100, sigmoid release nitrogen fertilizer, by 30%, 50% and 70% of total nitrogen applied. In the split application plot, 5 gN, 2 gN and 2 gN m^{-2} of ammonium sulfate were applied as basal dressing, topdressing at panicle formation, and reduction division stages, respectively.

2. Effect of continuous compost application on application of coated urea mixture to transplanted rice

The effects of long-term application of rice straw compost on the efficacy of single basal application of coated urea mixture were investigated under transplanting cultivation in experimental paddy fields of KNAES where 20 t ha^{-1} of compost had been applied for 30 years (compost plot) and control plot with no organic matter applied. A mixture of ammonium sulfate (50%) and sigmoid release coated urea SS100 (50%) was basally applied as coated urea mixture in this experiment. Coated urea SS100 is a type of fertilizer of which nitrogen release is suppressed for about 45 days after application and as much as 80% of the applied rate is released within with 100 days at water temperature of 25ºC including the initial 45 days (Fig. 1). Seven gN and 9 gN m^{-2} of basal dressing were applied to split and single basal application plots. Split application of ammonium sulfate was conducted in the same way as in the previous experiment.

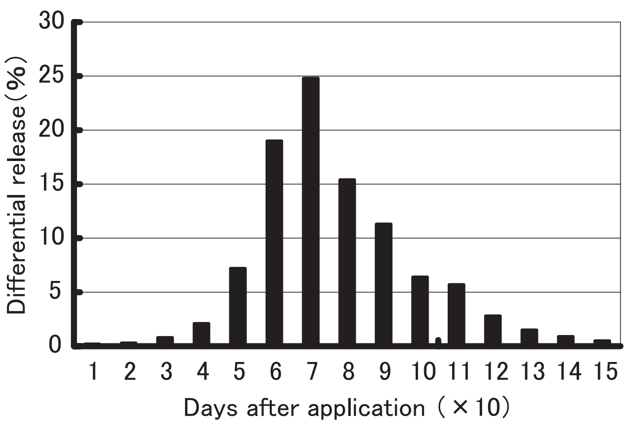

Fig. 1. Estimated nitrogen release from coated urea-SS100
Nitrogen from coated urea was released in water at a temperature of 25ºC.

3. Effect of coated urea on direct sown rice under dry condition with plowing

The experiment was carried out in a field of gray lowland soil at Chugoku National Agricultural Experiment Station, Fukuyama, Hiroshima Pref., Japan in 1985. Rice, cv. "Akenohoshi" was sown under dry condition at the seeding rate of 30 kg ha^{-1}. Nitrogen fertilizer was applied by two methods, split application of ammonium sulfate and single basal application of coated urea mixture. Each plot was divided into 2 subplots with total nitrogen amounts of 12 gN and 16 gN m^{-2}, respectively. Three gN and 7 gN m^{-2} of basal dressing were applied to each subplot of the split application, followed by 3 gN m^{-2} of topdressing at tillering, panicle formation, and reduction division stages, respectively.

4. Effect of coated urea on direct sown rice under flooded condition

The experiment was carried out in a field of gray lowland soil at KNAES, Chikugo, Fukuoka Pref., Japan. "Hinohikari" and strains of Saikai-232 and Saikai-238 were used as the rice cultivars. Seeds of rice coated with calcium peroxide were sown by a "shooting hill-seeder"[4] (Fig. 2) into the puddled paddy field with 30 cm of inter-row space and 15 cm of interhill space on June 6, 1999. Plots of split application with 9 gN m^{-2} of ammonium sulfate and single application with 7.5 gN and 6.5 gN of coated urea mixture were set up. A mixture consisting of linear release coated urea L50 (30%) and sigmoid release coated urea SS100 (70%) was used in this experiment.

Results and Discussion

1. Effect of application of mixed fertilizer containing ammonium sulfate and coated urea on transplanted rice

The effect of the single basal application of coated urea mixture was compared with that of split application of ammonium sulfate (Table 1). The average of 3 years was compared. Although a significant difference in yield was not found between sigmoid and split application, judging from the results obtained in 1994, it is considered that higher yields can be attained in single basal applications of fertilizer consisting of 50% to 70% of coated urea nitrogen than in split applications of ammonium sulfate. No significant difference was found also in yield components and in nitrogen content of grain among the methods of fertilization. However, single basal application using coated urea fertilizer is much more labor-saving than split application of ammonium sulfate. Additionally, nitrogen loss from paddy fields is considered to be less in cultivation by single basal application of coated urea mixture

Table 1. Growth and yield of paddy rice grown by transplanting cultivation under the application of nitrogen fertilizers containing coated urea and ammonium sulfate

Treatment block	Year	Yield in brown rice (t ha^{-1})	Index	No. of rice grains (×1,000 m^{-2})	No. of panicles (m^{-2})	No. of grains per panicle	Percentage of ripened grains (%)	Nitrogen content of brown rice (%)
No nitrogen	1994	5.76		28.1	291	97	91.5	1.22
	1995	3.41		21.3	251	85	75.1	1.16
	1996	4.15		22.1	244	91	88.8	1.20
	average	4.44a	(68)	23.8a	262a	91	85.1a	1.19a
Split application of ammonium sulfate	1994	7.17		34.2	369	93	92.1	1.36
	1995	6.27		32.2	366	88	85.4	1.32
	1996	6.09		30.1	342	88	90.6	1.29
	average	6.51b	(100)	32.2b	359b	90	89.4a	1.32b
Single basal application of coated urea mixture (30% of slow release N contained)	1994	7.21		35.9	424	85	90.8	1.32
	1995	6.21		35.2	460	77	80.1	1.35
	1996	5.95		31.8	349	91	87.3	1.27
	average	6.46ab	(99)	34.3b	411b	84	86.1a	1.31b
Single basal application of coated urea mixture (50% of slow release N contained)	1994	7.97		39.3	448	87	91.1	1.38
	1995	6.25		36.4	431	84	77.7	1.45
	1996	6.21		33.1	369	90	87.1	1.33
	average	6.81b	(105)	36.3b	416b	87	85.3a	1.39b
Single basal application of coated urea mixture (70% of slow release N contained)	1994	7.39		38.1	417	91	89.5	1.38
	1995	6.46		33.4	420	80	85.6	1.38
	1996	6.52		34.1	357	96	90.1	1.36
	average	6.79b	(104)	35.2b	398b	89	88.4a	1.37b

Rice, cv. "Hinohikari" was used in the experiment.
Significant at the 5% level between different alphabet according to t-test.

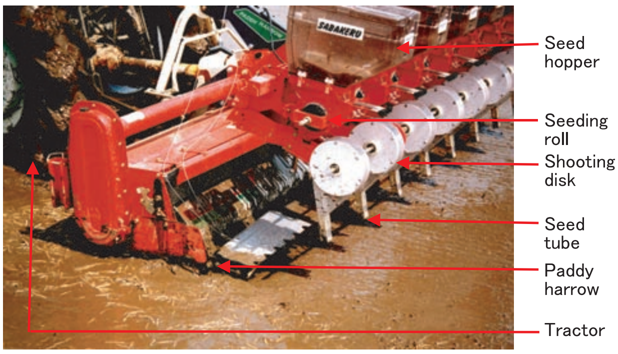

Fig. 2. Direct sowing of paddy rice under flooded condition by "shooting hill-seeder"

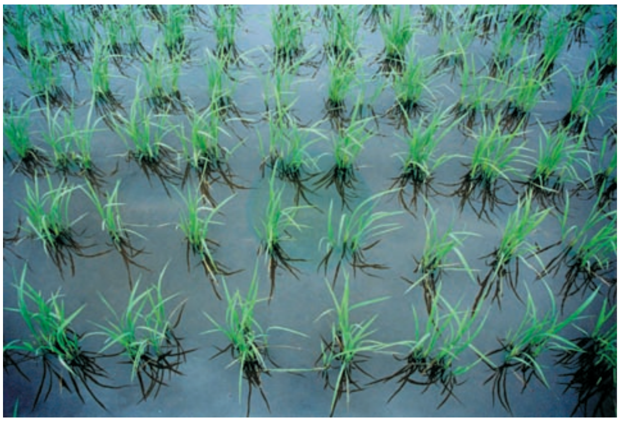

Fig. 3. Formation of rice hills at tillering stage seeded by "shooting hill-seeder"

Table 2. Yield of paddy rice grown by transplanting culture under application of coated urea mixture

Application of organic matter	Application methods of nitrogen	Amount of nitrogen applied ($g\ m^{-2}$)	Yield in brown rice ($t\ ha^{-1}$)		
			1995	1996	average
None	No nitrogen	0	3.23	4.36	3.80
	Split application of ammonium sulfate	7	4.83	5.30	5.07
	Split application of ammonium sulfate	9	5.60	5.91	5.76
	Single basal application of coated urea mixture	7	5.75	5.77	5.76
	Single basal application of coated urea mixture	9	5.92	6.33	6.12
20 $t\ ha^{-1}$ of compost	No nitrogen	0	4.67	4.73	4.70
	Split application of ammonium sulfate	7	5.84	6.52	6.18
	Split application of ammonium sulfate	9	5.86	6.77	6.32
	Single basal application of coated urea mixture	7	5.93	6.42	6.18
	Single basal application of coated urea mixture	9	5.84	6.53	6.19

Compost was applied continuously for 30 years. Rice, cv. “Hinohikari”was used in the experiment.

than in split application because nitrogen is released slowly. This cultivation method may reduce the amount of nitrogen affecting the environment[4].

2. Effect of long-term application of compost on application of coated urea mixture to transplanted rice

The effect of coated urea application on rice grown by transplanting cultivation under the condition of long-term compost application is shown in Table 2. Rice in the no nitrogen plot under compost application of 20 $t\ ha^{-1}$ had a yield more than 40% greater than the plot without compost application. The result shows that soil fertility in the compost plot was greater than in the no compost plot. In the no compost plot, rice yield in the coated urea plot was greater than that in the ammonium sulfate plot. Rice yield in the coated urea plot was almost equivalent to that in the ammonium sulfate plot when compared at the same level of nitrogen application.

On the other hand, under compost application, a significant difference in rice yield was not found between the plots of coated urea and the ammonium sulfate plots. Accordingly, the main advantage of basal application of coated urea under high levels of soil fertility consists mainly in the reduction of nitrogen applied and in the labor-saving.

3. Effects of coated urea on direct sown rice under dry condition with plowing

The effects of 2 levels of nitrogen application, 12 gN and 16 gN m^{-2}, on the yield are given in Table 3. The rice yield increased both in ammonium sulfate plots and in coated urea plots with the increase in nitrogen application. The percent yield increase was greater in the ammonium sulfate plots than in the coated urea plots on account of lower absorption efficiency of ammonium nitrogen. There was more than a 10% yield enhancement in coated urea plots compared with the same amount of nitrogen applied in ammonium sulfate plots (Table 3).

Concerning yield components, rice in the coated

Table 3. Yield, yield component and nitrogen absorption of paddy rice grown by direct sowing cultivation under dry condition

Application methods of nitrogen	Amount of nitrogen applied ($g\ m^{-2}$)	Yield in brown rice ($t\ ha^{-1}$)	Index	No. of grains (×1,000 m^{-2})	No. of panicles (m^{-2})	No. of grains per panicle	Percentage of ripened grains (%)	Nitrogen absorbed by rice plant ($g\ m^{-2}$)
Split application of	12	6.22	(100)	33.9	284	119	86.1	10.41
ammonium sulfate	16	6.89	(111)	37.2	260	143	88.2	12.59
Single basal application	12	7.05	(113)	39.0	300	130	85.4	12.17
of coated urea mixture	16	7.50	(121)	44.7	315	145	79.2	14.69

Paddy rice was grown by direct sowing cultivation under dry condition with plowing. Rice, cv. “Akenohoshi” was used in the experiment.

urea plots had a greater number of panicles than in the ammonium sulfate plots. The initial growth stage of rice plants in the coated urea plots was slow, but the nutritional condition of rice plants was maintained at proper levels because of a continuous nitrogen supply. It was connected with an increase in the panicle number. Compared with the same amount of nitrogen supply, yield in the coated urea plots was 10% to 13% greater than the ammonium sulfate plots. Rice both in the coated urea plots and in the ammonium sulfate plots showed an increase in nitrogen absorption in relation to the increased amount of nitrogen. The increase was 20% in both plots. Compared with the same amount of nitrogen supply, rice in the coated urea plots had 17% greater nitrogen absorption than in the ammonium sulfate plots.

Water permeability in paddy fields is generally greater in direct sowing cultivation under dry condition than in transplanting cultivation with puddling. Therefore, the efficiency of nitrogen absorption by rice plants is lowered due to leaching of nitrogen. Improvement of nitrogen absorption efficiency is important to increase yield. The utilization of coated urea is especially effective for improving rice yield in dry direct sowing. Lower absorption of applied nitrogen increases the nitrogen load to the surrounding water systems. Accordingly, the utilization of coated urea is effective in the establishment of nitrogen fertilizer for the preservation of the environment.

4. Effects of coated urea on direct sown rice under flooded condition

The effects of coated urea application on one cultivar and two strains of rice are shown in Table 4. In the case of "Hinohikari", which is now a leading cultivar in Kyushu, yields in the coated urea plots, 7.5 gN and 6.5 gN m^{-2} ,were a little lower than in the ammonium sulfate plot where 9 gN m^{-2} was applied, but in the case of the other 2 strains, yields were approximately equal to that in the ammonium sulfate plots. The effects of the 2 levels of reduced supply of nitrogen, 17% and 28%, were compared to each other and there were no significant differences between them. It was suggested that approximately 30% of the nitrogen could be reduced in a single basal application of coated urea compared with that in split application of ammonium sulfate.

In this experiment, direct sowing using a shooting hill-seeder was carried out. It is recognized that this direct sowing culture realizes a large amount of labor-saving, and hence is a positive utilization[6]. Among the various styles of direct sowing cultivation, direct sowing under flooded condition has a large share as it can be introduced to all conditions where transplanting cultivation can be practiced.

This shooting hill-seeder combined with a rotary

Table 4. Yield of paddy rice grown by direct sowing culture under the application of coated urea mixture

Fertilizer application (F) (g m^{-2})	Cultivar or strain (C)	Yield in brown rice (t ha^{-1}) Sowing date (B) 2-Jun	10-Jun	Average
Split application of ammonium sulfate N-9.0	Hinohikari	5.37	4.80	5.09
	Saikai-232	5.15	5.24	5.20
	Saikai-238	5.20	5.32	5.26
Single basal application of coated urea N-7.5	Hinohikari	5.10	4.78	4.94
	Saikai-232	5.02	5.12	5.07
	Saikai-238	5.04	5.66	5.35
Single basal application of coated urea N-6.5	Hinohikari	5.07	4.42	4.75
	Saikai-232	5.05	5.08	5.07
	Saikai-238	5.20	5.66	5.43

	Degree of freedom	F value
Block (B)	1	0.009ns
Fertilizer (F)	2	0.165ns
Cultivar (C)	2	2.924ns
F × C (interaction)	4	0.370ns

Result of analysis of variance was given regarding 2 sowing data as replication.
ns: not significant at 5% level.
Coated urea mixture consisted of linear release coated urea-50 (30%) and sigmoid release coated urea-100 (70%).

harrow for puddling has been spreading widely in Japan (Figs. 2 & 3). A prototype of this technique was developed by Shimotsubo & Togashi[5] and Togashi et al.[8–10]. The lodging resistance of plants was greater in hill-seeding cultivation than in other styles of submerged direct sowing[11–13]. Compacting of hill shape, sowing speed, durability of the machine, and other improvements were made by Tasaka et al.[7]. This direct sowing technique can result in large amounts of labor-saving in seeding and fertilizing when combined with a single basal application of coated urea.

5. Advantages in utilization of CRNF for rice cultivation

An advantage of CRNF utilization is that the different types of nitrogen supply can be chosen freely. Moreover, by utilizing the characteristics of slow release fertilizer, labor for fertilization, nitrogen absorption by plants and salt damage to plants can be improved. In addition to the convenient effect on rice culture, its preservative effect on the environment is recognized. Though quick release nitrogen fertilizer is lost easily from paddy fields, and hence can pollute the environment, the nitrogen of CRNF is hard to be lost because of its slow release characteristics. Therefore, the utilization of this fertilizer is a significant means in establishing fertilization techniques preservative to the environment.

In rice culture, whether transplanting or direct sowing, a great amount of labor saving can be attained by a single basal application of CRNF, and also the amount of applied nitrogen can be reduced without yield reduction.

Of course, there are some drawbacks to this fertilization technique. Therefore, reducing fertilizer costs, stabilizing the nitrogen release rate under fluctuating temperatures, decomposition of coating materials in soil, mixing of other agricultural chemicals in coating fertilizer and so on are future targets for improvement in this fertilization technique.

Nitrogen release from coated fertilizer is delayed at low temperature. Kato[2] indicated that the delay of nitrogen release at low temperature was prevented by giving the coated urea a character to change the release rate through contact with plant roots. As mentioned above, the study of CRNF has advanced considerably. Development of coated fertilizer with further convenient functions is expected.

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