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Comparison of Nitrogen Application Methods at the 4th Leaf Stage in Direct-Seeded Rice Field

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ABSTRACT : Two methods of nitrogen application at the 4th leaf stage were evaluated in direct-seeding rice cultivation on dry paddy soil: one was the top dressing of nitrogen on dry paddy condition before irrigation (TNDP) for labor saving, and the other was the top dressing of nitrogen on dry paddy with mechanical rotavation of the inter-row space (TNDPIR) for increasing the efficiency of nitrogen. To evaluate these two application methods, leaf chlorophyll contents, growth characteristics and yields were compared with two conventional methods, basal application (BA) and top dressing on flooded paddy condition at the 4th leaf stage (TNFP). The SPAD value of rice in TNDP was similar with that in TNFP throughout the whole growth stage of rice. Also, there were no differences in rice growth and yield between the two methods. However, in TNDPIR, the SPAD value was the highest during tillering stage among the four application methods, and the tiller number, LAI at heading stage and the panicle number were higher than the two conventional methods.

Key words **:** rice, nitrogen, direct seeding, labor saving.

Direct-seeding culture of rice was developed to solve the lack of rural labor and to raise the international competitiveness of our rice industry by reducing the production cost. However, direct-seeding cultivation on dry paddy soil still has a lot of problems such as weedy rice control, the stability of seeding method, unstable seedling establishment, low fertilizer efficiency, lodging, and weeds control, etc.

Nutrient deficiency is often observed in direct-seeded rice. Fast-releasing nitrogen fertilizers such as urea and ammonium sulfate etc. are used generally as a basal fertilizer to promote the initial growth in rice. But water soluble fertilizers like them are lost easily by leaching (Saigusa *et al.*, 1983). Especially in direct-seeding cultivation of rice, the period from seeding to seedling establishment is so long that the nitrogen applied basally before seeding is lost easily before it is absorbed in rice plant. Kim *et al* (1995) reported that top dressing of nitrogen was more advantageous in securing the panicle number and yield than basal dressing of nitrogen in direct-seeded rice on dry paddy.

Top dressing at the 4th leaf stage has been carried out conventionally in the flooded field condition. This situation makes rice farmers need more labor force because they have to work in the flooded field. Also, it is difficult to use agricultural machines on the flooded field such as applicator installed in tractor, weeder installed in combination farming machine, *et al.*

Therefore, TNDP and TNDPIR were evaluated for the growth characteristics and yield in comparison with the conventional methods of nitrogen application, BA and TNFP. TNDP was included for the working convenience of application and TNDPIR for increasing nitrogen use efficiency and controlling weedy rice.

MATERIALS AND METHODS

This experiment was carried out at the rice experimental field in National Crop Experiment Station for 2 years from 1998 to 1999. The rice cultivar, Juanbyeo was used. Disinfected and air-dried seeds of rice were seeded on dry paddy soil with drill seeder with 30 cm interrow space, and with the seeding rate of 50 kg/ha on the 21st of April in 1998, and on the 23rd of April in 1999.

Total N applied was 150 kg/ha, which was splitted three times. Split application rate of nitrogen was 40-30-30%. The first 40% of nitrogen was applied with urea by four methods as shown in Table 1, then top dressing of the second 30% of nitrogen was applied at the 5~6th leaf stage in BA, at the 7~8th leaf stage in the other treatments. The last 30% of nitrogen was applied at the panicle initiation stage in all treatments. Amount of phosphorus and potassium applied was 70 kg/ha, and 80 kg/ha respectively. Total phosphorus was applied basally. Potassium was applied two times, at the basal and panicle initiation stage, with the split application rate of 70-30%.

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Table 1. Nitrogen application methods in rice direct seeding on dry paddy soil.

Treatments†	Nitrogen application methods	Application time
BA	Basal application	Before seeding
TNFP	Top dressing on flooded paddy	4th leaf stage
TNDP	Top dressing on dry paddy	〃
TNDPIR	Mechanical rotavation of interrow space after top dressing on dry paddy	〃

†BA, TNFP : Conventional methods.
TNDP, TNDP IR : Trials of nitrogen application.

As shown in Table 1, in conventional application methods nitrogen was applied as basal dressing when the field was plowed just before seeding (BA) and top dressing on flooded paddy just after irrigation at the 4th leaf stage (TNFP). As for the two trials of nitrogen application, it was applied as top dressing on dry paddy just before irrigation on dry soil condition (TNDP). After top dressing by the same method of TNDP, the interrow spacing was mechanically rotavated by weeder installed in combination farming machine just before irrigation (TNDPIR). The mechanical soil rotavation depth was about 7~10 cm in 1998, and 4~5 cm in 1999. The other cultural management was carried out in accordance with the standard direct-seeded rice cultivation method of the Rural Development Administration (RDA, 1998).

Growth characteristics and yields were investigated. The SPAD value was measured with chlorophyll meter (Minolta SPAD-502, Japan) at important growth stages to grasp the trend of nitrogen nutrition status.

RESULTS AND DISCUSSION

Seedling characteristics were compared between basal dressing (BA) and top dressing treatments at 35 days after seeding (Table 2). There were no differences in all initial growth characteristics of the seedlings except leaf age between basal application and top dressing of nitrogen. The leaf number of rice seedling in the basal treatment of nitrogen was greater 0.7 than that in top dressing treatment of nitrogen. However, this did not affect the subsequent growth and yield. Therefore, it was shown that the nitrogen applied to soil as basal dressing before seeding did not help the seedling growth during initial growth stage.

When the field was irrigated from one corner of the field after top dressing, nitrogen can move horizontally on the paddy surface along with water flow from the water entrance to the opposite site. If the nitrogen applied on the soil surface moved with the flow of the water, the SPAD value of the rice plant near the water entrance would be lower than that in the long distance from the water entrance. Therefore we estimated this phenomenon by measuring SPAD value of rice on the different distant spots from the water entrance (Table 3). There were no differences among the SPAD val-

Table 2. Initial growth characteristics of direct seeded rice on dry paddy soil according to nitrogen application time.

Nitrogen application time	Leaf age	Meso-cotyl length (cm)	Coleop-tile length (cm)	1st leaf length (cm)	2nd leaf sheath length (cm)	2nd leaf blade length (cm)	Plant height (cm)
Basal	4.8	0.0	1.2	1.8	3.9	1.6	11.4
4 leaf stage	4.1	0.1	1.5	2.2	4.1	1.5	10.9
LSD (0.05)	0.7	NS	NS	NS	NS	NS	NS

*The data of 1998 and 1999 were averaged in this table, and they were investigated just before top dressing at 35 days after seeding.

Table 3. Estimation of horizontal movement of nitrogen along with the water flow in the field by use of the leaf chlorophyll content after nitrogen application on dry paddy soil.

Distance from the water entrance (m)	Leaf chlorophyll content (SPAD)†			
	1998		1999	
	Application after irrigation	Application before irrigation	Application after irrigation	Application before irrigation
5~10	39.1 a‡	37.2 a	37.3 a	37.4 a
20~25	38.4 a	39.0 a	37.0 a	38.7 a
40~45	37.6 a	38.0 a	37.0 a	38.6 a
Mean	38.4	38.1	37.1	38.2

†Investigation time : 10 days(1998) and 11 days (1999) after application
‡The common letters indicate the significant difference at 5% probability level by DMRT.

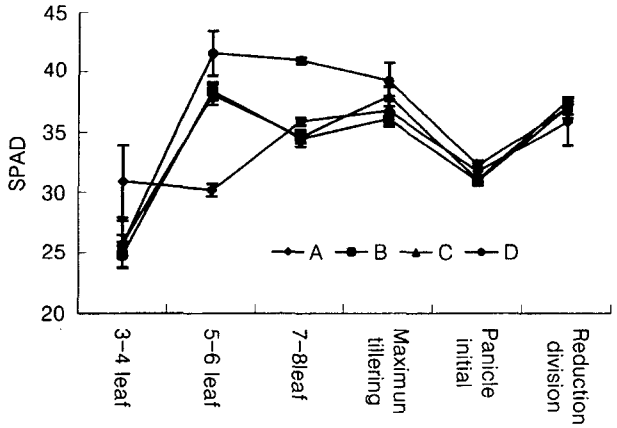

Fig. 1. Time course of chlorophyll content (SPAD) during rice growth time. The data of 1998, 1999 were averaged (A: BA, B: TNFP, C: TNOP, D: TNDPIR).

ues according to the distances from the water entrance. This suggests that there was no practical problem about the movement of nitrogen fertilizer by irrigation.

Many researchers reported that chlorophyll-meter could measure nitrogen amount in rice plants by using the correlation between chlorophyll content and nitrogen content in leaf (Inada, 1994; Tyubachi *et al,* 1986; Pettygrove, 1991; Turner and Jund. 1991). To evaluate the effects of the four nitrogen application methods on nitrogen status of rice, the leaf chlorophyll content (SPAD) was measured during rice growth stage (Fig. 1). Out of four methods, the SPAD value in rice fertilized with basal dressing was the lowest at 5~6th leaf stage. This might have been due to the fact that nitrogen applied as basal dressing was lost by leaching and denitrification caused by the transformation of ammonia to nitrate in dry soil for a month before irrigation (Reddy and Patrick, 1976). Wilson *et al* (1989) reported that it took about 21 days for nitrogen to be absorbed by rice plant in basal dressing treatment, but less than 3 days in top dressing treatment. It is reasonable, therefore, that nitrogen had to be applied as top dressing to prevent the loss during initial growth stage in dry seeding rice culture.

The time course of SPAD value in rice fertilized on dry paddy condition before irrigation at the 3rd~4th leaf stage (TNDP) was similar with that fertilized on flooded paddy condition after irrigation (TNFP) during the whole rice growth period. However, the SPAD value in rice treated by mechanical soil rotavation after nitrogen application (TNDPIR) maintained highest during the tillering stage among four treatments. This result meant that nitrogen mixed in the soil was more advantageous to be absorbed by rice plant than soil surface-applied nitrogen. There were many reports that surface-applied urea was lost by volatilization and denitrification (Matocha, 1976; Fenn and Richards, 1986; Ashok *et al,* 1996). Therefore, the nitrogen mixing with soil could reduce the nitrogen losses and simultaneously put nitrogen near the rhizosphere.

The plant growth characteristics at heading stage were shown in Table 4. Like SPAD readings, there were no differences in the rice growth characteristics between TNDP and TNFP.

In the plot treated by mechanical rotavation of interrow space after top dressing on dry paddy, the tiller number and the LAI were a little higher than the others in 1999. However, tiller number of rice treated with mechanical soil mixing was rather less than the other treatments in 1998. The reason why tiller number was low in 1998 was the mechanical damage of seedlings by deep rotavation. The seedling stand decreased by 37.7% at that time (data not shown). Therefore, the soil mechanical rotavation depth was controlled to about 4~5 cm to reduce the damage of rice seedlings in 1999.

Rice yields and yield components were shown in Table 5. All yield components and yields were not different between TNDP and TNFP in 1998 and 1999. Therefore, it is advisable that rice farmers apply urea in dry paddy condition for their working convenience at the 4th leaf stage in dry seeding rice culture.

In TNDPIR, the number of panicles per square meter was

Table 4. The plant growth characteristics at heading stage.

Year	Treatments	Heading date (month.date)	Plant height (cm)	Tiller no. (no/m^2)	LAI	Dry weight (g/m^2)
1998	BA	Aug.20	96.3 a†	313 a	5.2 a	958 a
	TNFP	Aug.20	97.0 a	323 a	5.3 a	1003 a
	TNDP	Aug.20	97.3 a	320 a	5.4 a	1005 a
	TNDPIR	Aug.20	99.3 a	274 b	5.1 a	947 a
1999	BA	Aug.18	92.0 a	285 b	4.8 b	979 a
	TNFP	Aug.18	91.3 a	289 b	4.9 ab	1003 a
	TNDP	Aug.18	88.3 a	337 ab	5.3 ab	1036 a
	TNDPIR	Aug.18	90.9 a	373 a	5.6 a	1089 a

†The common letters indicate the significant diference at 5% probability level by DMRT.

Table 5. Rice yields and yield components according to nitrogen application methods.

Year	Treatments	Panicle no. (no./m^2)	Grain no. (no/panicle)	Ripened grain (%)	1000 grain weight of brown rice (g)	White rice yield (ton/ha)
1998	BA	312 a†	91.2 b	93.6 a	20.6 a	4.98 a
	TNFP	323 a	90.2 b	95.7 a	20.1 a	5.13 a
	TNDP	318 a	91.3 b	95.4 a	20.2 a	5.09 a
	TNDPIR	272 b	103.2 a	94.4 a	20.2 a	4.98 a
1999	BA	284 b	101.1 a	86.6 a	22.6 a	4.76 a
	TNFP	271 b	103.5 a	87.6 a	22.3 a	5.04 a
	TNDP	304 ab	95.9 a	86.8 a	22.9 a	5.05 a
	TNDPIR	334 a	102.6 a	86.1 a	22.7 a	5.37 a

†The common letters indicate the significant diference at 5% probability level by DMRT.

Table 6. The effect of the soil rotavation after nitrogen application on the reduction of weedy rice.

Soil rotavation	1998		1999	
	Weedy rice (plant/m^2)	Control value (%)	Weedy rice (plant/m^2)	Control value (%)
Non-treated†	0.37	-	1.41	-
Treated	0.12	67.6	0.56	60.3
LSD (0.05)	0.17		0.89	

†The data of BA, TNFP, TNDP were averaged.

272 in 1998, and 373 in 1999. It was the lowest in 1998 and the highest in 1999 among the four treatments. These results reflected the reason for the tiller number reduction in plant growth characteristics. In 1998, grain number compensated the decrease in panicle number to get similar yield with the others. In 1999, panicle number was the highest, which resulted in the highest yield, 5.37 t/ha among the four nitrogen application methods although it was not significant statistically. Generally, the major factor determining yield is to secure sufficient panicle number in direct-seeded rice in dry paddy soil. With respect to increasing panicle number in dry seeding, the method for mechanical soil rotavation after nitrogen top dressing at initial growth stage can possibly be used as a practical method to increase yield.

Weedy rice was controlled in addition to the increase in nitrogen efficiency in TNDPIR. As shown in Table 6, weedy rice occurred at a density of 0.37 plant/m^2 in 1998 and 1.41 plant/m^2 in 1999. But by mechanical rotavation of interrow space with weeder attached to combination farming machine, weedy rice was controlled at the rates of 60.3% and 67.6% in 1998 and 1999, respectively.

At present weedy rice is one of the most difficult problems in direct-seeded rice, but there is no method to control it effectively. Therefore, weedy rice has to be treated with integrated control system including chemical, cultural, mechanical, and biotechnical methods. It is highly possible that if this nitrogen application method is used as a mechanical control method in integrated control system, it will raise the control value effectively.

In conclusion, top dressing of N at the 3rd to 4th leaf stage on dry paddy condition is advisable rather than that on flooded paddy condition because there was no difference in yield and growth characteristics between the two methods, and former method can offer the farmers working convenience and the environment to use various agricultural machines such as fertilizer applicator installed in tractor, and weeder installed in combination agricultural machine. Mechanical rotavation of interrow space could increase nitrogen efficiency and also reduce weedy rice occurrence.

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