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Seedling Growth and Yield of Rice as Applying Slow Release Nitrogen Fertilizers Mixed with Seed Bed Soil in Seedling Box

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ABSTRACT : Experiments were conducted to find out the optimum level of slow release N fertilizers when total amounts of nitrogen required throughout the growing season in paddy were applied in the soil of seedling box. To evaluate the emergence rate and growth of rice seedlings, five levels of Meister (MS) 10, MS S10, and latex coated urea (LCU) which are equivalent to 0, 40, 60, 80, and 100 kg N ha^{-1} were mixed in soil of the seedling box. Emergence rate differed depending on the fertilizers and N levels; in MS 10 plots the emergence rate was 40.8% at 40 kg N ha^{-1} and no seedlings were emerged at the higher levels, in MS S10 plots higher than 80% at all the N levels, and decreased with the N levels from 70.0% at 40 kg N ha^{-1} to 59.5% at 100 kg N ha^{-1} of LCU. Seedling started to wilt at 40 kg N ha^{-1} of MS 10 and 80 and 100 kg N ha^{-1} N of LCU on the 8th day after sowing, while seedling growth was normal at all the levels of MS S10. Field performance of rice was evaluated at the 0, 30, 60, 90, 120 kg N ha^{-1} of MS S10 applied in the soil of seedling box and N was not applied in paddy. Grain yield at 90 and 120 kg N ha^{-1} of MS S10 was similar to conventional urea split application (120 kg N ha^{-1}), but significantly higher compared to 30 and 60 kg N ha^{-1} of MS S10. Fertilizer N recovery decreased with N levels and the N recovery at 90 kg N ha^{-1} of MS S10 and conventional urea split application were 62.2% and 44.2%, respectively, with similar grain yield. The optimum level of MS S10 to be applied in seedling box seems to be about 90 kg N ha^{-1} considering grain yield, price of fertilizer, labor applying fertilizer, and fertilizer N recovery.

***Keywords* :** N release rate, Electrical conductivity, Slow release N fertilizer, Rice, Seedling growth, Yield, N recovery

Nitrogen (N) is the most important mineral nutrient in growing rice. If the total amount of N required throughout the growing season is applied during the land preparation, N urea will be dissolved in water quickly. Therefore, significant amounts of N would be subjected to leaching or denitrification loss before taking up by the plants (De Datta *et al*, 1968). Also, the high N content at early growth stage may cause the incidence of rice blast diseases and lodging problems due to elongated lower internodes at panicle initiation stage. To reduce N loss and plant damages, traditionally about 50% of N fertilizers are incorporated into soil as basal and the remaining 50% are applied at tillering, panicle initiation, and heading stages (Lee, 1986). However, the recovery of fertilizer N ranges only 30-40% due to the leaching and denitrification loss (De Datta *et al.*, 1968; Ryu, *et al*, 1994). The leached N stimulates algal growth in the fresh water of streams or lakes and it may cause the death of fish due to the lack of oxygen during the decay of algae and N_2O formed during the denitrification processes is one of the green house gases causing global warming (Shoji, 1997; Lee *et al.*, 1995). Also, the split application of N requires more labor and causes the high production cost of rice. Therefore, the new N fertilizers and application methods of the fertilizers are needed to protect environments and to reduce the production cost to compete with foreign rices.

Many slow release N fertilizers were incorporated into the soil at the time of land preparation for transplanting. Sulfur coated urea (SCU) and latex coated urea (LCU) supply N at the similar rate throughout the growing season, so the number of tillers and panicles are reduced due to lack of N at the tillering stage when lots of N are required to produce tillers. Therefore, the addition of urea to LCU increased the number of tillers (Park, 1992; Yoo *et al.*, 1997). However, rice root may be damaged by the sulfur contained in SCU under the reduced soil conditions and it is difficult to apply evenly due to the floating of the fertilizer on the water and moving around. However, the polyolefin coated slow release N fertilizer, Meister (MS) 10 and MS 15 produce sufficient tillers without adding extra urea and adopted by rice farmers in Japan and Korea to save labors for top dressing of N although the price of the fertilizers are quite expensive. Such slow release N fertilizers still require labor to be applied in the large area of paddy although they showed quite high N recovery of 60-80% (Park and Kim, 1995).

In Japan, MS S10 and MS S15 were developed to apply the total amounts of N required throughout the growing season in seedling box without damaging seedlings because it did not dissolve during the first 30 days (Shoji, 1997). The

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fertilizers released N continuously near the root system after transplanting and increased fertilizer N recovery up to 83% (Shoji, 1997). Also, it does not require labor to apply N fertilizers in the field.

These experiments were conducted to select the best slow release N fertilizers to apply all the amounts of N in the soil of rice seedling box and to find out the optimum level of the fertilizers under the field conditions.

MATERIALS AND METHODS

This study was conducted on the Agricultural Research Farm, Yeungnam University in Kyongsan, Korea in 1999. A japonica rice variety, 'Ilmibyeo' was used.

The slow release N fertilizers were Meister (MS) 10, MS S10, and latex coated urea (LCU). MS 10 and MS S10 were produced by a Japanese fertilizer producing company, Chisso-Asahi Ltd. and LCU was produced by a Korean fertilizer producing company, Chobi Co. Ltd. Both MS 10 and MS S10 were made by coating urea with polyolefin and LCU with latex. N analysis of all the slow release N fertilizers was 40%.

To measure the N releasing time of the slow release N fertilizers, 5 g of the samples were put into a 500 ml beaker and added 200 ml distilled water and stored at 15.0, 22.5, and 30.0°C for 1, 3, 5, 7, 10, 15, 20, 25, and 30 days. The released N was analyzed by the micro-Kjeldhal method and EC was measured using an EC meter (Mettler-Toledo MC126 Conductivity Meter, Switzerland) after filtering the solutions through a Whatman #42 filter paper. N releasing rate (%) was calculated by the following formula; [amount of N dissolved in solution/N in 5 g of sample (2.0 g)]×100. Experiment was conducted in a split plot design with three replications; slow release N fertilizers as main plot, N levels as subplot.

To investigate the upper limit of the slow release N fertilizers for the emergence and growth of seedlings, 0, 400, 600, 800, 1,000 g N were mixed with three liters of commercial seed bed soil in a seedling box (equivalent to 0, 40, 60, 80, 100 kg N ha^{-1} when 250 boxes seedlings were transplanted in a hectare). The seed bed soil contained 0.06, 0.01, and 0.02% of N, P_2O_5, and K_2O, respectively and produced by Samkeyung Chemical Co. Ltd. in Korea.

According to the results of the above experiment the most promising MS S10 was used to test growth and yield of rice in the paddy field at the same N levels of MS S10 as used in the above rice seedling growth experiment. For the conventional urea split application, seedlings grown without slow release N fertilizers were transplanted at 120 kg N ha^{-1} of urea in the paddy. The urea was applied at the time of land preparation, 14 days after transplanting, 25 days before heading, and heading stage at the ratio of 50, 20, 20, and 10%, respectively. In all treatments 70 kg P_2O_5 ha^{-1} and 80 kg K_2O ha^{-1} were applied at the time of land preparation. One hundred and sixty grams of seeds were sown in each seedling box on 1 May, 1999 and transplanted on 20 May by a four-row rice transplanter. The experiment was conducted in a randomized block design with four replications. Plant height, the number of tillers, and dry matter were measured from June to September at the 10 days intervals. N content of the plants was analyzed by a micro-Kjeldahl method and fertilizer N recovery was calculated as follows:

Fertilizer N recovery (%)=[(N absorbed in N fertilized plots – N absorbed in no N fertilized plot)/Amounts of N applied] × 100.

Leaf area index (LAI) was measured at the heading stage using LI-3000 Portable Area Meter (LI-COR, U.S.A.). Total chlorophyll content of leaves was measured at the heading stage by extracting with 80% acetone and measured absorbance at 652 nm in a spectrophotometer (Kontron, Italy). Other observations were made according to the Agricultural Observation Standards published by the Rural Development Administration.

RESULTS AND DISCUSSIONN

Releasing rate and EC of slow release N fertilizers

The N releasing rates of the slow release N fertilizers in water differed depending on temperatures and fertilizers (Fig. 1). The released N of MS 10 and LCU increased linearly until 30 days after the initiation of experiment at all temperatures and the N releasing rate increased with temperatures. The N releasing rate of MS 10 was higher compared to LCU at all temperatures. However, N releasing rate of MS S10 was very low until 30 days after the initiation of experiment at the all temperatures except at 30°C of which N releasing rate started to increase rapidly from 25 days after the initiation of experiment. Park and Kim (1995) also reported that N of MS S15 was not significantly released until 10 days after the initiation of experiment at 30°C, but LCU released N linearly with time.

The changes in EC of slow release N fertilizers are shown in Fig. 2. On the first day EC of both MS 10 and LCU at 15, 22.5, and 30°C were about 0.2, 0.5, and 0.6 ds/m, respectively. EC of MS 10 increased significantly with time, while EC of LCU changed little for 30 days at the all temperatures. However, EC of MS S10 was much lower than that of MS 10 and LCU and it continuously increased with time at 22.5 and 30°C, while was not changed significantly at 15°C.

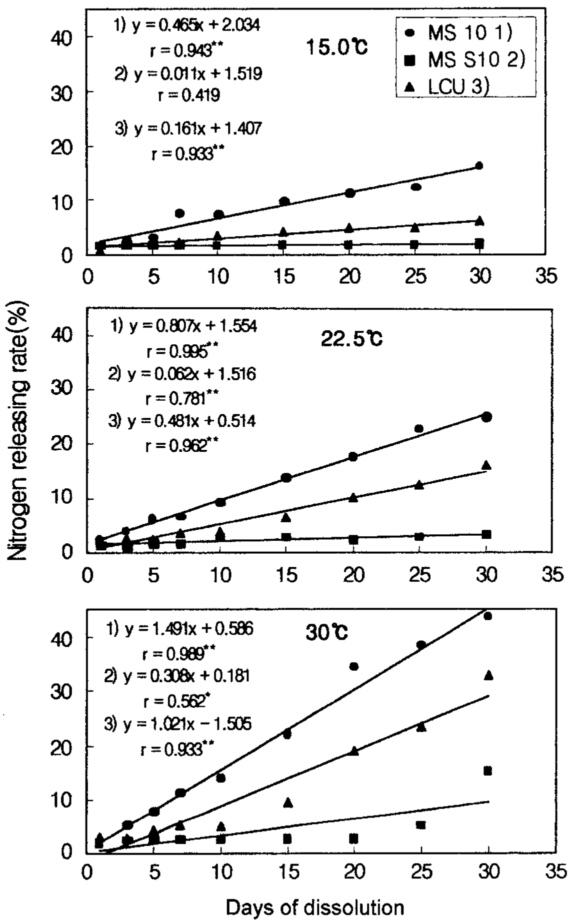

Fig. 1. Nitrogen releasing patterns of MS 10, MS S10 and LCU in water at 15.0, 22.5 and 30.0°C.

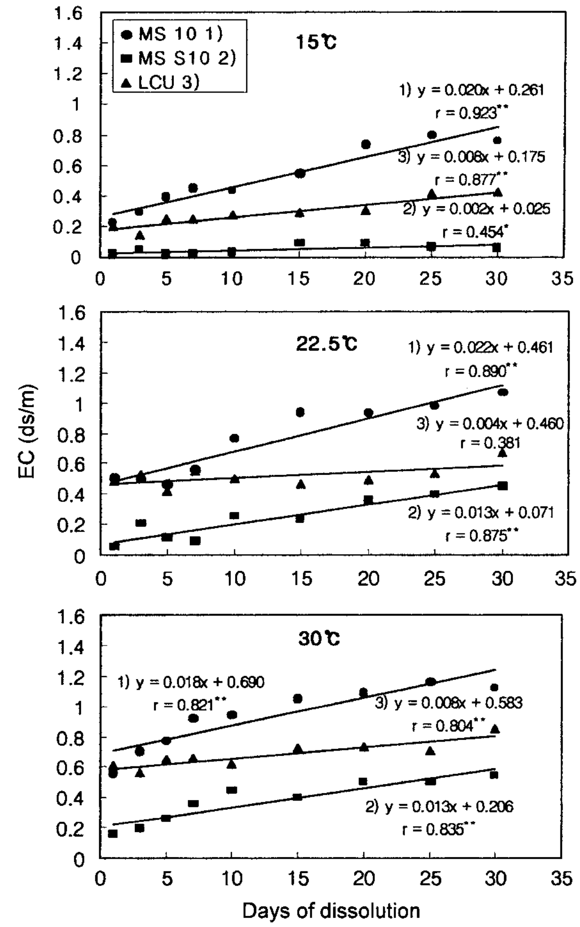

Fig. 2. Changes in EC of MS 10, MS, S10 and LCU in water at 15.0, 22.5 and 30.0°C.

Table 1. Emergence rate, plant height, the number of leaves, dry weight, N concentration, and seedling damages of 12 days old seedlings grown in the seedling box at the different levels of MS 10, MS S10, and LCU.

Slow release fertilizer	N levels (kg ha^{-1})	Emergence rate (%)	Plant height (cm)	No. of leaves	Dry Wt. (g/100 plants)	Nitrogen (%)	Damage (1-5)
MS 10	0	90.8 a†	11.2 ab	2.0 a	2.17 ab	2.36 e	1‡
	40	40.8 f	3.2 e	1.4 b	1.44 c	2.40 de	4
	60	0.0 g	0.0 f	0.0 c	0.00 d	0.00 f	-
	80	0.0 g	0.0 f	0.0 c	0.00 d	0.00 f	-
	100	0.0 g	0.0 f	0.0 c	0.00 d	0.00 f	-
MS S10	0	90.8 a	11.2 ab	2.0 a	2.17 ab	2.36 e	1
	40	83.6 abc	11.8 a	2.0 a	2.49 a	2.93 abc	1
	60	89.2 ab	9.8 bc	2.0 a	2.26 ab	2.67 bcde	1
	80	85.9 ab	9.6 bc	2.0 a	2.28 ab	2.88 bcd	1
	100	80.4 bcd	9.4 bc	2.0 a	1.89 abc	3.16 ab	1
LCU	0	90.8 a	11.2 ab	2.0 a	2.17 ab	2.36 e	1
	40	79.0 bcd	9.2 c	2.0 a	1.83 bc	3.46 a	1
	60	74.4 cd	8.8 c	2.0 a	2.01 ab	3.08 abc	1
	80	69.6 de	5.3 d	2.0 a	2.05 ab	2.83 bcde	3
	100	59.5 e	5.2 d	1.9 a	2.17 ab	2.56 cde	3

†Same letter within a column are not significantly different by DNMRT at the 5% level.
‡Visual damages of seedlings (1-5): 1 normal, 5 severe wilting.
Data were analysed after arcsin transformation for emergence rate and square root transformation for other factors.

Emergence rate and seedling growth

Emergence rate, plant height, the number of leaves, and dry weight and N content of 12 days old seedlings grown in seedling boxes are shown in Table 1. Interaction was significant between slow release fertilizers and N levels in all factors, thus means of all the N levels of three slow release fertilizers were compared. During the seedling stage day time temperature ranged from 30 to 35°C and night temperature from 15 to 18°C. The emergence rate at 40 kg N ha^{-1} of MS 10 was 40.8% and seedlings were not emerged at all at 60, 80, 100 kg N ha^{-1} probably due to too high EC as shown in Fig. 2. Plant height, the number of leaves, and seedling dry weight at 40 kg N ha^{-1} of MS 10 were significantly lower compared to control (no N applied, seed bed soil only). The seedlings at 40 kg N ha^{-1} with MS 10 started to wilt on the 8th day after sowing and showed severe damages on the 12th day.

In MS S10 plots the emergence rate was higher than 80% at all the N levels and it was similar to unfertilized control plot. Plant height decreased as the N level increased. The number of leaves and seedling dry weight at 40, 60, and 80 kg N ha^{-1} were similar to those of control plot, but the growth of seedlings tended to be retarded at 100 kg N ha^{-1}. However, the N content of seedlings increased as the amounts of N increased.

In LCU plots the emergence rate decreased with the N levels from 79.0% at 40 kg N ha^{-1} to 59.5% at 100 kg N ha^{-1}. Plant height decreased as the N level increased, but the number of leaves, seedling dry weight, and N content of seedlings were similar among the N levels or did not show consistent trends. Seedlings started to wilt at 80 and 120 kg N ha^{-1} on the 11th day and showed severe damages on the 12th day after sowing.

The N recovery of MS S10 applied in the seedling box was 83.3% (Shoji, 1997) and it was twice of conventionally applied urea, 120 kg N ha^{-1}, in the paddy. Therefore, at least 60 kg N ha^{-1} should be applied in the seedling box to supply sufficient N throughout growing season in the paddy without seedling damages. MS 10 is not proper to be applied in the seedling box, because of the poor emergence rate and seedling growth due to a fast N release (Fig. 1) and high EC (Fig. 2) even at the 40 kg N ha^{-1}. LCU may be applied in the seedling box if the 10 days old and younger seedlings are transplanted or the fertilized seed bed soil is replaced with unfertilized soil. Park and Kim (1995) also reported that the highest limit of LCU was 80 kg N ha^{-1}. LCU always has dangers subjected to the low emergence rate and severe fertilizer burn at the unseasonably high temperature and prolonged seedling stages. MS S10 is the only good slow release N fertilizer to apply in the seedling box due to the slow release of N and low EC during the first 30 days.

Growth of rice in paddy field

To find out the optimum N level of MS S10 in the field, MS S10 equivalent to 0, 30, 60, 90, and 120 kg N ha^{-1} were mixed with bed soil and transplanted in paddy without N application. The changes in the plant height, the number of tillers, and dry weight of plants throughout growth stages are shown in Fig. 3. The plant height increased up to 16 September and leveled off at all treatments and was higher as the N levels of MS S10 increased. Plant height at the 120 kg N ha^{-1} of conventional urea split application was similar to the 60 kg N ha^{-1} of MS S10 at early growth stages, but similar to 90 kg N ha^{-1} of MS S10 at the late growth stages.

The number of tillers per hill at 90 and 120 kg N ha^{-1} was highest, followed by that at 30 and 60 kg N ha^{-1} of MS S10 and 120 kg N ha^{-1} of conventional urea split application.

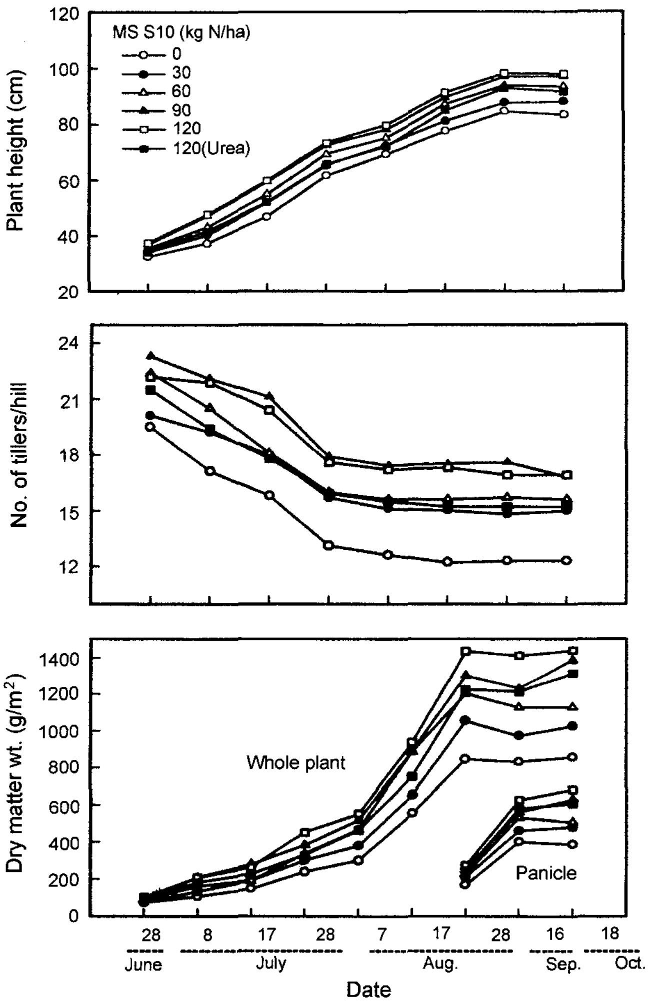

Fig. 3. Changes in plant height, the number of tillers, and dry matter weight at the different levels of MS S10.

Table 2. Heading date, leaf area index (LAI), chlorophyll content, and the lengths of culms and panicles at the different N levels of MS S10 at heading stage.

Level of MS S10 (kg N ha^{-1})	Heading date	LAI	Chlorophyll (mg/g Fr.Wt.)	Culm length (cm)	Panicle length (cm)
0	23 Aug.	2.9 b‡	3.50 c	60.2 d	18.1 ns
30	22 Aug.	3.1 b	4.26 b	65.8 c	17.9
60	22 Aug.	4.5 a	4.42 ab	68.7 bc	18.4
90	22 Aug.	5.0 a	5.16 a	71.2 ab	18.3
120	22 Aug.	5.0 a	4.86 ab	73.2 a	18.1
120†	22 Aug.	4.2 a	5.11 a	66.7 c	18.7

†Conventional urea split application.
‡Same letter within a column are not significantly different by DNMRT at the 5% level.

Table 3. Yield and yield components at the different levels of MS S10.

Level of MS S10 (kg N ha^{-1})	No. of panicles per hill	No. of spikelets per		Ripened grains(%)	1,000 grain Wt. (g)	Yield in brown rice (kg N ha^{-1})	Grain/Straw ratio
		Panicle	m^2(× 1000)				
0	12.1 c‡	70.3 b	18.8 d	94.9 ns	20.6 b	3.4 d	0.91[ns)]
30	14.1 abc	73.7 b	21.4 cd	92.8	20.6 b	4.0 c	0.83
60	15.5 ab	74.0 b	25.4 bc	92.9	20.1 c	4.5 bc	0.82
90	17.1 a	81.9 ab	30.7 a	90.2	20.0 cd	5.2 a	0.71
120	16.7 a	86.5 ab	32.1 a	93.1	19.8 d	5.3 a	0.77
120†	13.1 bc	97.0 a	27.9 ab	87.7	21.1 a	5.1 ab	0.96

†Conventional urea split application.
‡Means within a column followed by same letter are not significantly different by DNMRT at the 5% level.

Without N application the number of tillers per hill reduced significantly compared to any N fertilized plots. Transplanting was made on 20 May and at the time of the first tiller observation, 28 June, rice plants could be around time of the maximum tillering stage (Park, 1992). Therefore, the number of tillers decreased and leveled off.

Dry weight of whole plants was similar among N levels at the early growth stage, but the differences in dry matter gradually increased as plant growth advanced. During the ripening stages the dry matter increased as the N levels of MS S10 increased and that of conventional 120 kg N ha^{-1} of urea split application was between 60 and 90 kg N ha^{-1} of MS S10. The similar trend was also reported by Park and Kim (1995).

Heading date, leaf area index (LAI) and chlorophyll content at heading stage, culm length, and panicle length are shown in Table 2. Without N application heading date was delayed by a day compared to other N applied plots probably due to a little slower vegetative growth and development.

LAI, chlorophyll, and culm length generally increased as N levels of MS S10 increased. LAI and chlorophyll content of conventional 120 kg N ha^{-1} of urea split application were similar to those of MS S10 between 60 and 120 kg N ha^{-1}. The culm length at the 90 and 120 kg N ha^{-1} of MS S10 plots was taller compared to the conventional urea split application probably due to the continuously released N until the internode elongation stage. Generally, the taller culm length is positively correlated with the lodging at ripening stage, so this factor should be considered to introduce slow release N fertilizers.

Grain yield and yield components

The number of tillers per hill, the number of spikelets per panicle and per square meter, and grain yield increased as N levels increased although the percentage of ripened grains and 1,000 grain weight were similar among the N levels as shown in Table 3. In the conventional plot, the number of panicles per hill was 13.1 and it was lower, but the number of spikelets per panicle was much higher compared to the MS S10 applied plots. At the conventional urea split application the smaller number of tillers per hill compared to 60, 90, and 120 kg N of MS S10 was the results of continuously lower tiller number throughout vegetative growth stages (Fig. 3). These lower tiller and panicle numbers and lower dry weight at the early growth stage in conventional urea split application plot (Table 3 and Fig. 3) may indicate that significant amounts of urea applied during the land preparation as basal might be lost, but N top dressing applied at the panicle formation stage could increase the number of spikelets per panicle and panicle weight (Table 3 and Fig. 3). However, continuously released N from MS S10 could increase both the number of panicles per hill and spikelets

Tab le 4. Nitrogen uptake and the fertilizer nitrogen recovery.

MS S10 (kg N ha^{-1})	Straw			Panicle			Nitrogen	
	Dry Wt. (ton ha^{-1})	N (%)	N (kg ha^{-1})	Dry Wt. (ton ha^{-1})	N (%)	N (kg ha^{-1})	Total N (kg ha^{-1})	Fert. N recovery (%)
0	4.5 d	0.47 d	21 d‡	4.0 d	1.07 b	43 d	64 c	-
30	5.9 c	0.54 cd	32 cd	4.8 c	1.07 b	53 c	85 b	66.7 a
60	7.3 ab	0.55 cd	40 bc	5.5 b	1.11 b	61 bc	101 ab	60.0 a
90	8.3 a	0.66 ab	53 a	5.8 ab	1.19 a	68 ab	121 a	62.2 a
120	8.3 a	0.58 bc	48 ab	6.3 a	1.14 ab	71 a	119 a	45.8 b
120†	6.6 bc	0.67 a	45 ab	6.0 ab	1.20 a	72 a	117 a	44.2 b

†Conventional urea split application.
‡Same letter in a column are not significantly different by DNMRT at the 5% level.

per panicle.

Grain yield at 90 and 120 kg N ha^{-1} of MS S10 was similar to 120 kg N ha^{-1} of conventional urea split application although it was reduced significantly at 30 and 60 kg N ha^{-1} of MS S10. This indicates that about 25% of N can be reduced when 90 kg N of MS S10 is applied in the soil of seedling box without yield reduction. The similar grain yield between 90 and 120 kg N of MS S10 probably came from the lower fertilizer N recovery at the 120 kg N of MS S10 which will be shown in Table 5 later.

The panicle/straw ratio decreased as N level increased. This indicates that continuously released N of MS S10 stimulated more straw than panicle.

N uptake and fertilizer N recovery

At harvest time straw and panicle weight, N uptake, and fertilizer recovery are shown in Table 4. The weight and N uptake of straw and panicle generally increased as N levels increased although concentrations were relatively similar among the N levels.

Fertilizer N recovery tended to decrease as N level increased. At 90 kg N ha^{-1} of MS S10 the fertilizer N recovery was 62.2% and it was 18.0% higher than that at the conventional urea split application of 44.2%. This N recovery of MS S10 mixed with seed bed soil was much lower than 83% reported by other research workers (Wada, 1991; Shoji, 1997), but similar to the basal application in the field (Ueno *et al.*, 1990) in Japan. The differences N recovery among the experiments may come from the different environmental conditions such as soil type, temperature, etc.

Conclusion

All the amounts of N required in the paddy field can be applied in the soil of rice seedling box as a slow release N fertilizer, MS S10, without fertilizer burn of seedlings because it is released slowly and showed low EC at the first 30 days. However, MS 10 released N at the fast rate, showed high EC, and reduced emergence rate and seedling growth significantly even at the very low N level of 40 kg N ha^{-1}, so MS 10 can not be used in seedling box. LCU may be used in the seedling box if manufactured to release a little bit slowly, used unfertilized heavy soil which holds more N, or increased amounts of bed soil, etc.

MS S10 can be applied up to 120 kg N ha^{-1} in the seedling box without seedling damages, but the optimum MS S10 level was 90 kg N ha^{-1} considering grain yield and amounts of fertilizer. Compared to the conventional urea split application, the amounts of N can be reduced without yield reduction if applied in seedling box as MS S10 due to a high N recovery. Also it reduces labor appling N fertilizer and N_2O production which causes global warming (Shoji, 1997). If technologies controlling the releasing time of agricultural chemicals are developed in the future, herbicides, fungicides, and insecticides as well as P and K fertilizers may be applied in the seedling box. The technologies will save chemicals and labor applying the chemicals and also, it will contribute to protect environments.

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REFERENCES

De Datta, S. K., C. P. Magnaye, and J. C. Moomaw. 1968. Efficiency of fertilizer nitrogen (^{15}N-labelled) for flooded rice. Trans. 9th Int. Soil Sci. Congr., *Adelaide. Australia.* IV : 67-76.

Lee, E. W. 1986. Rice Production. Hyangmoonsa. p. 354.

Lee, S. M., S. H. Yoo, and K. H. Kim. 1995. Changes in concentrations of urea-N, NH_4-N and NO_3-N in percolating water during rice growing season. *J. Kor. Soc. Soil Sci. Fert.* 28(2) : 60-164.

Park, K. B. 1992. Effect of the whole-layer application of slow-release fertilizer on growth and yield of rice. *Kor. J. Crop Sci.* 37(6) : 499-505.

Park, K. B. and M. T. Kim. 1995. Effect in the characteristics of infant seedling and the growth of rice plant in paddy field by incorporation with coated urea fertilizer in nursery box soil. *J. Kor. Soc. Soil Sci. Fert.* 28(1) : 83-87.

Ryu, K. S., S. H. Yoo, and K. C. Song. 1994. Movement of applied nutrient through soils by irrigation. Effect of soil water on the movement of nitrogen. *J. Kor. Soc. Soil Sci. Fert.* 27(3) : 232-237.

Shoji, S. 1997. New Environment Protecting Agriculture. Seunilsa (Japanese and translated into Korean by K. B. Park).

Ueno, M., K. Kumagai, J. Sato, M. Inoue, and N. Tanaka. 1990. Basal fertilizer application technology utilizing soil nitrogen and coated slow release fertilizer (No. 2). A basal fertilizer application system based on the prediction of soil nitrogen release and the recovery of coated fertilizer. Agri. and Hort. 65(11) : 46-50 (Japanese).

Wada, G., R. C. Aragones, and H. Ando. 1991. Effect of slow release fertilizer (Meister) on the nitrogen uptake and yield of the rice plant in the tropics. *Japan. J. Crop Sci.* 60(1) : 101-106.

Yoo, C. H., B. W. Shin, S. B. Lee, J. H. Jeong, S. S. Han, and S. J. Kim. 1997. Effect of latex coated urea on nitrogen use efficiency and yield in drill seeded rice. *J. Kor. Soc. Soil Sci. Fert.* 30(2) : 114-121.

Yoshihiro, K. 1995. Innovation of fertilizer application by using controlled-release fertilizer. 2. The single application of fertilizer in nursery box to non tillage transplanted rice. *Japan. J. Soil Sci. Fert.* 66(2) : 176-181.