Nitrogen Management with Split Application of Urea for Direct-Seeding Rice in Wet Paddy

Ho Jin Lee*, Jun Han Seo*, Jung Sam Lee*, Yong Sang Jung**, and Fred E. Below***

ABSTRACT

Direct-seeding has major advantages such as labor and cost saving by eliminating preparation of seed bed and transplanting. But, it required increased input of fertilizers and pesticides because of the extended paddy period. Direct seeding in wet paddy (DSWP) gives faster growth and more uniform seedling emergence than direct-seeding in dry paddy. This research had an objective to develop an efficient N management practices for DSWP with split application of N fertilizer. A paddy field experiment was conducted to evaluate effects of starter N and N-topdressing which was delayed N application until 5-leaf stage, with comparison to transplanting (TP). Total amount of N application were two levels; 110kg and 77kg/ha. The N applications were split four times during rice growth stages; starter, topdressing at 5-leaf stage, top dressing at tillering stage, and topdressing at panicle initiation stage. DSWP had more tillers/m² than TP, but with the delayed heading. The DSWP plots which received N-topdressing at 5-leaf stage without starter N had higher leaf area index (LAI) and leaf greenness than the TP plot. Also, these DSWP plots had high leaf-N concentration at the heading stage, as calculated from leaf chlorophyll meter readings.

Rice yield in DSWP with N-topdressing at 5-leaf stage was significantly higher than that in TP and in DSWP with starter N. Energy and N use efficiency were improved in DSWP with N-topdressing at 5-leaf stage. But, there were no significant differences in grain yield between the two levels of total amounts of N applications, 77kg and 110kg/ha. We concluded that starter N could not be used effectively by rice seedlings, but topdressing N at 5-leaf stage was an efficient N management for rice growth and yield in DSWP system.

Key words: direct seeding, nitrogen management, application method, agronomic efficiency.

Rice farming in Korea needs labor saving and high gaining culture system to reduce farming costs and to protect the environment. Direct seeding has been adopted as the most efficient method of planting rice in the developed countries where labor supply was limited and expensive. Labor cost in rice farming reached 28% of the total cost. Especially, labor input in nursing seedling and transplanting required 13-15% of total rice farming cost, in 1993.

Direct seeding is more advantageous than transplanting, because it eliminates labor demands for seedbed preparation and seedling care, pulling seedlings, hauling, and transportation. Furthermore, it avoids the transplanting damage and is more conducive to mechanization.

Transplanting is gradually being replaced by direct-seeding as labor becomes a decisive cost factor (De Datta, 1986). Furthermore, new herbicides make weed control possible in direct-seeded paddy where weeds have been more of a problem than for transplanting. However, direct seeding techniques and proper mechanization for the system are not well-established, thus its productivity fluctuates with weather patterns.

Rice production in the existing high-input and intensive rice farming has been achieved by heavy application of fertilizers, pesticides, and herbicides. In these processes, excess N fertilizer over optimum level in which N was not utilized immediately by the plant has led to nitrate contamination in surface and ground water (Lee and Park, 1993).

We have reported that direct seeding in wet paddy produced rice yield no less than transplanting, and that it was an effective labor-saving rice culture method (Lee et al., 1996). However, unlike transplanting, direct-seeded rice seedlings in wet paddy may not require the large amount of fertilizer until the 5-leaf stage when it takes over a month for the rice seedling to grow. During this period, starter N fertilizer can be lost easily in N transformation processes. Common practice in DSWP depends mainly on starter N application. Therefore, a proper N management for direct-seeded rice should be established to improve uptake of N fertilizer and agronomic efficiencies. This study compared the efficiencies of topdressing at 5-leaf stage and basal surface application, for direct seeding in wet paddy.

The objectives of this research were to (1) evaluate efficient N management practices in direct-seeding in wet paddy (DSWP), (2) determine DSWP yield response to N levels and application times, and (3) compare agronomic efficiency of the DSWP with various combination of urea application timing and level.

MATERIALS AND METHODS

Field experiments were conducted on sandy loam soil of paddy fields at College Farm, Seoul National University, Suwon. The rice cultivar, 'Geumobyeo', was either transplanted (40-days old seedlings) at hill spacing of 30 cm by 15 cm (22 hills/m²) on 28 May, 1996, or direct-seeded in puddled wet soil in rows (12-hour presoaked seeds at 56kg dry seed per ha) using an 6-row drum planter at 25-cm spacing on 16 May, 1996.

*Department of Agronomy, Seoul National University, Suwon 441-744, Korea.
**Department of Agricultural Chemistry, Kangwon University, Chunchon 200-701, Korea.
***Department of Crop Science, University of Illinois, U.S.A.
Received 22 Dec. 1997.

Paddy field plots were laid out in five treatments combined with urea-N levels and split application methods, including conventional rice transplanting plot (T1) and were replicated three times (Table 1).

Weeds were controlled either by surface scattering granular type herbicide, "Nonanme" on transplanted plots at 30kg/ha at one week after transplanting, or by surface scattering the same herbicide on direct-seeded plots at 30kg/ha immediately and at 40 days after seeding. All plots were harvested at 50 days after heading using the combine.

Leaf greenness was determined by using the chlorophyll meter, Minolta SPAD-502, on the flag leaf. Leaf N content was determined by Auto Kjeldahl Nitrogen Analyzer.

RESULTS AND DISCUSSION

Growth characteristics

Direct-seeded rice exhibited the faster crop establishment and more tiller number than transplanted rice. Maximum tiller number was observed higher in topdressed at 5-leaf stage than in starter N applied rice (Fig. 1).

Previous studies (Dingkuhn et al., 1990a; Schnier et al., 1990) have shown a higher tiller number plant^{-1} in direct-seeded than in transplanted rice under the identical plant population and spacing. According to Matsuchima (1980), low shoot N concentration may impede the development of a sufficient number of leaves per tiller, required for a tiller to become autotrophic. Thus, the high tiller abortion rates of direct-seeded rice can be related to low plant N.

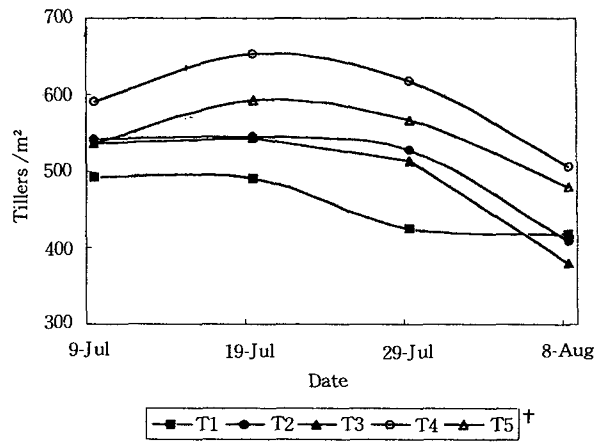

Fig. 1. Seasonal changes in the number of tillers affected by application levels and times of N fertilizer.

† T1: transplanting, N 90kg/ha, T2: DSWP, N 110kg/ha, starter N application, T3: DSWP, N 77kg/ha, starter N application, T4: DSWP, N 110kg/ha, topdressing at 5-leaf stage, T5: DSWP, N 77kg/ha, topdressing at 5-leaf stage.

As the growth characteristics at 10 days after heading show (Table 2), the heading date in topdressing at 5-leaf stage was delayed for 5 days, compared to that of starter N application. This could be related to high leaf N content in the topdressing methods during the vegetative growth stage. The topdressing methods increased the plant vigour as indicated by higher panicle length, higher

Table 1. Split N application methods in fertilizer treatments with different rice seedings.

Treatment	Seeding method	Total N (N kg/ha)	Starter N (%)	Top-dressing at 5LS† (%)	Top-dressing at TS‡ (%)	Top-dressing at PIS§ (%)
T1	TP¶	90	56	–	22	22
T2	DSWP#	110	40	–	30	30
T3	〃	77	30	–	35	35
T4	〃	110	–	40	30	30
T5	〃	77	–	30	35	35

†5-leaf stage, ‡ Tillering stage, §Panicle initiation stage, ¶Transplanting, #Direct-seeding in wet paddy

Table 2. Growth characteristics in different treatments of N fertilizer application and rice seeding at 10 days after heading.

Treatment†	Heading date	Length of panicle(cm)	LAI	Chrolophyll meter reading
T1	Aug 4	19.65^{b}	5.00^{b}	40.6^{ab*}
T2	Aug 7	18.74^{c}	3.64^{c}	37.3^{c}
T3	Aug 7	19.28^{bc}	3.33^{c}	39.9^{b}
T4	Aug 12	20.71^{a}	5.74^{a}	41.1^{a}
T5	Aug 12	20.86^{a}	4.81^{b}	39.9^{b}

* Means in a column not followed by the same letter are significantly different at $P \leq 0.05$ based on LSD.

† T1: transplanting, N 90kg/ha, T2: DSWP, N 110kg/ha, starter N application, T3: DSWP, N 77kg/ha, starter N application, T4: DSWP, N 110kg/ha, topdressing at 5-leaf stage, T5: DSWP, N 77kg/ha, topdressing at 5-leaf stage.

LAI and higher leaf N content, compared with starter N applications. The maintenance of high LAI and SPAD value during the grain filling period could provide higher canopy CO_2 assimilation in topdressed rice plants.

Relationship between chlorophyll meter reading and leaf N content

The chlorophyll meter provides to measure quickly and easily the leaf greenness which is affected by leaf chlorophyll content. The leaf greenness is also influenced by internal factors, such as N status and age of the plant tissue.

In this experiment, leaf N concentration was determined by using the Minolta SPAD-502 reading within various times and samples. The relationship between the chlorophyll meter reading and leaf N concentration showed the linear regression, $y = 0.91x - 0.039$ (Fig. 2). It indicated that the chlorophyll meter can detect N deficiencies of rice plants, and has the potential to be used for improving N management.

N topdressed at 5-leaf stage rice produced more tillers than starter N application did. This increment was probably caused by maintaining high N and the tiller abortion rates of the former was lower than those of the latter (T1: 15%, T2: 25%, T3: 30%, T4: 22%, T5: 19%).

During the reproductive and ripening stages, lower leaf N concentration could depress canopy CO_2 assimilation and crop growth rate of direct-seeded rice. Lower leaf N concentration was caused by dilution and not by reduced uptake (Schnier et al., 1990). The plant's N status at panicle initiation stage and thereafter influences spikelet differentiation and, thus, yield potential (Kumura, 1956; Wada and Matsuchima, 1962).

In this experiment, topdressing at 5-leaf stage maintained higher leaf N content than starter N application did during the reproductive and ripening stages. Thus, the topdressing method had the more spikelet differentiation to achieve high yield potential (Fig. 3).

Grain yield and yield components

Topdressing at 5-leaf stage increased grain yield significantly compared with starter N application (Table 3).

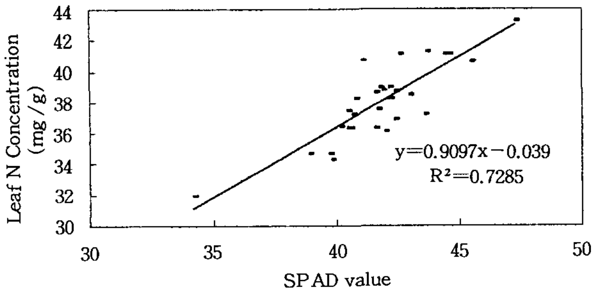

Fig. 2. Relationship between chlorophyll meter reading and leaf N concentration.

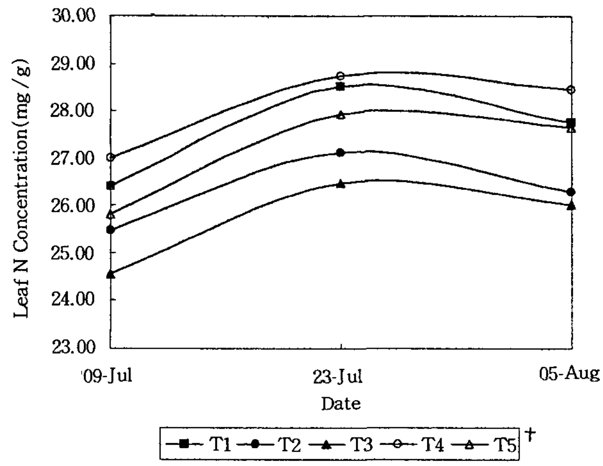

Fig. 3. Seasonal changes of leaf N concentration affected by different treatments of N fertilizer application.

† T1: transplanting, N 90kg/ha, T2: DSWP, N 110kg/ha, starter N application, T3: DSWP, N 77kg/ha, starter N application, T4: DSWP, N 110kg/ha, topdressing at 5-leaf stage, T5: DSWP, N 77kg/ha, topdressing at 5-leaf stage.

The highest grain yield was obtained in the T4 plot. Especially, topdressing at 30% rate of the total N fertilizer at 5-leaf stage (T5) resulted in a higher yield than starter N application, and even higher than transplanting. How-

Table 3. Yield and yield components in different treatments of N fertilizer application and rice seeding.

Method†	No. of panicles per m²	No. of spikelets per panicle	Ripened grains(%)	1000-grain weight(g)	Yield (Mg/ha)
T1	418[b]	97.9[b]	78.00[a]	25.66[a]	5.08[b*]
T2	408[b]	88.8[c]	83.11[a]	25.93[a]	4.64[bc]
T3	380[b]	88.9[c]	82.11[a]	25.73[a]	4.26[c]
T4	507[a]	111.7[a]	79.89[a]	25.48[a]	6.12[a]
T5	480[a]	110.2[a]	80.33[a]	25.97[a]	5.96[a]

* Within traits, means in a column not followed by the same letter are significantly different at $P \leq 0.05$ based on LSD.

† T1: transplanting, N 90kg/ha, T2: DSWP, N 110kg/ha, starter N application, T3: DSWP, N 77kg/ha, starter N application, T4: DSWP, N 110kg/ha, topdressing at 5-leaf stage, T5: DSWP, N 77kg/ha, topdressing at 5-leaf stage.

ever, there was no significant difference in rice yields between T4 and T5. This indicates that the additional N of 33kg/ha did not contribute to increased grain yield and may lead to more loss of nitrate N.

According to Dingkuhn et al. (1990a), in direct-seeded rice, plant N content during the spikelet differentiation may have limited spikelet number per panicle more than in transplanted rice because of significantly lower tissue N concentrations.

In this experiment, the yield increments in topdressing at 5-leaf stage were related to the high spikelet number per area by maintaining the high leaf N concentrations (Table 3).

Energy and N use efficiency

In aspects of improving low-input sustainability, energy input for rice farming and N efficiency were calculated as following the method of our previous paper (Lee et al., 1996; Pimentel, 1980). Energy use efficiency for rice production in the treatments T4 and T5 was greater than with starter N application, T2 and T3, even transplanting, T1. Nitrogen use efficiency in topdressing at the 5-leaf stage was also greater than other treatments. The highest nitrogen use efficiency was obtained with topdressing at 30% rate of the total N fertilizer at the 5-leaf stage (Table 4).

Thus, we concluded that the topdressing at 5-leaf stage instead of starter N had a better chance to obtain high yields and to improve the energy and N use efficiency for direct seeding in wet paddy.

For rice farming to increase its low-input sustainability, transplanting can be replaced with direct seeding into waterlogged paddy. Direct seeding in wet paddy gives better seedling emergence and faster growth than direct-seeding in dry paddy. Also, nitrogen fertilizer should be applied at optimum amounts at a threshold level to prevent nitrate contamination and water pollution, especially, in paddy soil with high sand content. The chlorophyll meter can be a useful tool to determine N status of rice plant and to make the decision for additional N application or cancel next N topdressing. Further study is necessary to determine the optimum N level for each cultivar and field condition.

Table 4. Comparison of energy and N use efficiency of rice culture in different treatments of N fertilizer application.

Method†	Energy use efficiency for rice production (10^{-3} kg grain/kcal)	Nitrogen use efficiency (kg grain/kg N)
T1	1.453	32.14
T2	1.385	26.39
T3	1.308	31.79
T4	1.680	32.02
T5	1.831	44.53

† T1: transplanting, N 90kg/ha, T2: DSWP, N 110kg/ha, starter N application, T3: DSWP, N 77kg/ha, starter N application, T4: DSWP, N 110kg/ha, topdressing at 5-leaf stage, T5: DSWP, N 77kg/ha, topdressing at 5-leaf stage.

ACKNOWLEDGEMENTS

This study is supported by the Korean Ministry of Education through research fund.

REFERENCES

ASPAC. 1985. Proceedings of the international symposium on alternative sources of energy for agriculture. Taiwan Sugar Research Institute. Taipei. Taiwan. p. 416-431.

Cox, G. W. and M. D. Atkins. 1979. Agricultural ecology (an analysis of world food production systems). W. H. Freeman and company. San Francisco. p. 597-629.

De Datta, S. K. 1986. Technology development and the spread of direct seeded flooded rice in Southeast Asia. Fert. Res. 9: 171-186.

______ and Buresh, R. J. 1989. Integrated nitrogen management in irrigated rice. Advances in Soil Science 10: 143-169.

Dingkuhn, M., H. F. Schnier, S. K. De Datta, E. Wijangco, and K. Dörffling. 1990a. Diurnal and developmental changes in canopy gas exchange in relation to growth in transplanted and direct-seeded flooded rice. Aust. J. Plant Physiol. 17: 119-134.

______, ______, ______, K. Dörffling, C. Javellana, and R. Pamplona. 1990b. Nitrogen fertilization of direct-seeded flooded vs. transplanted rice: II. Interactions among canopy properties. Crop Sci. 30: 1284-1292.

Kumura, A. 1956. Studies on the effect of internal nitrogen concentration of rice plant on the constitutional factor of yield. Proc. Crop Sci. Soc. Jpn. 24: 177-180.

Lee, H. J., J. H. Seo, J. S. Lee, Y. S. Jung, and J. K. Park. 1996. Low-input and energy efficiency of direct seeding method in rice. Korean J. Crop Sci. 41: 115-122.

______ and K. Y. Park. 1993. Crop production system for low-input sustainable agriculture in Korea. Low-input sustainable crop production systems in Asia. KSCS. Korea. p. 43-58.

Loomis, R. S. and D. J. Connor. 1992. Crop ecology (productivity and management in agriculture systems). Cambridge Uni. Press. New York. p. 400-427.

Matsushima, S. 1980. Rice cultivation for the million. Jpn. Sci. Soc. Press. Tokyo.

Pimentel, D. 1980. Handbook of energy utilization in agriculture. CRC Press. New York. p. 3-98.

Rao, M. V., B. B. Reddy, B. C. Ghosh, and M. M. Panda. 1985. Nitrogen management in direct sown intermediate deep water rice(15-50cm): I. Effect of form, method and time of urea N application on growth, yield and N uptake. Plant and Soil 83: 243-253.

Saini, A. S., R. K. Patel, and R. V. Singh. 1986. Energy use in rice-based farming system in India. International-Rice-Research-Newsletter. 11(4): 42-43.
______ , ______ , and ______ . 1987. Energy management in rice production. International-Rice-Research-Newsletter. 12(4): 61-62.
Schnier, H. F., M. Dingkuhn, S. K. De Datta, K. Mengel, E. Wijangco, and C. Javellana. 1990a. Nitrogen economy and canopy carbon dioxide assimilation of tropical lowland rice. Agron. J. 82: 451-459.
______ , ______ , ______ , ______, and J. E. Faronilo. 1990b. Nitrogen fertilization of direct-seeded flooded vs. transplanted rice: I. Nitrogen uptake, photosynthesis, growth, and yield. Crop Sci. 30: 1276-1284.
Wada, G. and S. Matsushima. 1962. Analysis of yield-determining process and its application to yield prediction and culture improvement of lowland rice: LXIII. Proc. Crop Sci. Soc. Jpn. 31: 23-26.