Effect of Nitrogen Split Application Methods on Development of Vascular Bundle and Yield Components of Rice Cultivars

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ABSTRACT: This experiment was conducted to evaluate the effect of split application of nitrogen(N) on development of vascular bundle(VB) and yield components of rice. Two cultivars were used in this study; IR58, an indica type and Shinunbongbyeo, a japonica type. The number and total cross sectional area of the VB in the peduncle and leaf blade were more and bigger in N split application than 100 percent basal fertilizer. Nitrogen split application at necknode differentiation stage increased the number and size of the VB. Nitrogen split application resulted in increased panicle number with application of N before transplanting and at tillering stage; increased spikelets number with N application at necknode differentiation stage; and increased spikelet fertility and 1000 grain weight with N application at necknode differentiation and heading stages. Grain yield increased 7~10% in N split as compared to all basal application. The total cross sectional area of VB in peduncle closely correlated with the number of spikelets per panicle. Nitrogen management can have an impact on spikelet differentiation through more and bigger VB and increase grain yield potential.

Keywords : rice, nitrogen, split application, vascular bundle, development, yield.

In the development of large panicles with many primary branches (Vergara *et al.*, 1990), the vascular bundles play an important role. The number of large vascular bundles (LVB) and small vascular bundles (SVB) is closely correlated with the number of primary branches (Hayashi, 1976a), number of secondary branches (Chae *et al.*, 1984; Lee *et al.*, 1985) and number of spikelets (Chae *et al.*, 1984; Lee *et al.*, 1985). The development of VB is affected by cultivars (Chae *et al.*, 1984), nitrogen (Yamazaki, 1963; Lee *et al.*, 1985; Lee *et al.*, 1994; Lee *et al.*, 1996), potassium (Noguti, 1940), silica (Okamoto, 1970), and temperature (Sato, 1979). Increased N fertilizer application resulted in increased number of VB, number of primary and secondary branches of the panicle, and number of spikelets per panicle. The rice plant requires N throughout its growth and for spikelet filling. When the plant is deficient in N, it displays yellowing of leaves due to an inhibition of chlorophyll synthesis. Matsushima (1980) suggested that N fertilizers applied during the early growth as basal dressing and topdressing at the necknode differentiation to the initial stage of spikelet differentiation increase panicle number and number of differentiated spikelets. At the reduction division stage, N prevents the degeneration of spikelets and enlarge the size of hulls; and at the ripening stage, it increases the percentage of ripened grains and enhances the development of the caryopsis.

The purpose of this study is to increase yield potential by increasing the number and cross sectional area of VB due to split application of N.

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MATERIALS AND METHODS

This field experiment was conducted in 1990 dry season at the block E32 of the IRRI experiment farm. Rice cultivars were used IR 58, an indica type and Shinunbongbyeo, a japonica type. A strip plot design with split application of N as horizontal factor, varieties as vertical factor were used for the field experiment (Table 1). The experiment was replicated three times. The plot size measured 4 × 2.4 m. There were 36 experimental units (2 varieties × 6 N treatment × 3 replications).

The soil was plowed and harrowed 2 to 3 times with tractor for good leveling and soil homogeneity. Small bunds were constructed around each fertilizer treatment with a canal between the treatments for drainage and irrigation.

Table 1. Scheme of the split application treatment based on percent of total nitrogen rate.

Treatments	Fertilizer(%)			
	Basal	Tillering stage	Differentiation of necknode	Heading stage
1	25	25	25	25
2	30	20	30	20
3	30	30	40	-
4	50	20	20	10
5	70	-	20	10
6	100	-	-	-

Table 2. Number and cross sectional area of large (LVB) and small (SVB) vascular bundles in the peduncle as affected by split application of nitrogen.

Split application treatments (%)		Number of VB				Area of VB ($X10^{-3}mm^2$)			
		LVB		SVB		LVB		SVB	
		IR58	Shinunb-ongbyeo	IR58	Shinunb-ongbyeo	IR58	Shinunb-ongbyeo	IR58	Shinunb-ongbyeo
25-25-25-25		21.7 b†	11.0	20.3	25.0	15.62	14.54	2.53	2.66
30-20-30-20		21.3 b	11.7	22.3	25.3	15.75	14.68	2.58	2.79
30-30-40-0		23.7 a	11.7	22.7	24.7	16.07	15.02	2.56	2.75
50-20-20-10		22.0 b	12.0	21.0	24.0	15.63	14.98	2.49	2.82
70-0-20-10		22.3 b	12.0	23.0	24.0	15.74	14.52	2.57	2.81
100-0-0-0		21.3 b	11.3	21.0	23.3	15.28	14.07	2.35	2.71
F-value	Cultivar	79.06**		20.21**		41.36**		16.54**	
	N split application	3.67*		0.92 ns		2.08 ns		0.72 ns	
	Interaction	2.21 ns		0.72 ns		0.27 ns		0.34 ns	

†Means followed by a common letter in a column are not significantly different at the 5% level by DMRT.
*,**means are significantly different at 5% and 1% level, respectively.

Total N applied was 120 kg/ha which is the normal rate in the IRRI field during the dry season. Phosphorus and potassium at 40 kg/ha each were applied with the basal N. Sources of fertilizer were ammonium sulfate (21% N), solophos (18% P_2O_5) and muriate of potash (60 K_2O). Fifteen-day-old seedlings, which were raised in seedling trays in the greenhouse, were transplanted by hand at 20 × 20 cm spacing. Three seedlings were planted per hill and replanting was done when needed one week later. The water level was maintained at 5~10 cm during 30 days after transplanting. Plots were continuously flooded until about 2 weeks before harvest. Pests and diseases were controlled whenever necessary. Weeds were controlled chemically and by hand weeding.

One hundred twenty five hills (5 m^2) were harvested. Grain yield was computed at 14 moisture content. The yield components were determined from five hills: Number of panicles per unit area, number of spikelets per panicle, percent filled spikelets, and 1000-grain weight. Tiller production was monitored and sampling was by tiller order. Peduncle, flag leaf blade and leaf sheath from the two cultivars were sampled for measuring vascular bundle. For the leaf blade, the widest part of the middle region were collected. The materials were fixed in 80 ethyl alcohol solution. The free-hand transverse section were made. The number and cross sectional area of VB were determined from peduncle and leaf blade using a microscope.

RESULTS AND DISCUSSION

Development of vascular bundle

IR58 has marked increase in LVB number and area at 30-30-40-0 N split application (Table 2). This means large application of N at necknode differentiation stage can increase the number and area of the LVB in IR58. In general when N was all applied basal (100-0-0-0), both cultivars had low number of LVB and SVB and also in cross sectional area of the VB. Although initial high N might be useful, sustained high N level especially at panicle initiation stage is needed in order to have high number of LVB. This is possible by application of N at panicle initiation and most effective at a high dose of N. The except that 30-30-40-0 N split application, there was no significant different in the number and cross sectional area of the LVB and SVB in the peduncle of various N split application treatments. IR58 had more LVB and SVB than Shinunbongbyeo. This results agree with report that indica cultivars develop more VB than japonica cultivars (Lee *et al.*, 1992, Lee *et al.*, 1996).

The response in terms of the VB in the flag leaf blade was the same pattern as those in the peduncle (Table 3). High N application at panicle initiation stage (differentiation of the necknode) can result in better VB production. The difference in varietal sensitivity to N split application generally agree with the findings of Lee (1984) who found indica cultivars to have better VB with N application.

The more VB in peduncle had been associated with more differentiation of primary and secondary branches and also more spikelets. Larger and more VB in leaf blade and peduncle would facilitate translocation of photosynthates to the panicle, thus giving rise to better spikelet filling.

Yield and yield components

Grain yield was lowest at treatment 100-0-0-0 in IR58 and 25-25-25-25 for Shinunbongbyeo (Table 4). Grain yield was highest at 70-0-20-10 with 5.56 t/ha and at 50-20-20-10 with

Table 3. Number and cross sectional area of large (LVB) and small (SVB) vascular bundles in the flag leaf blade of the main culm as affected by split application of nitrogen.

Split application treatments (%)	Number of VB				Area of VB ($X10^{-3}mm^2$)			
	LVB		SVB		LVB		SVB	
	IR58	Shinunbongbyeo	IR58	Shinunbongbyeo	IR58	Shinunbongbyeo	IR58	Shinunbongbyeo
25-25-25-25	16.0	14.3	62.0	62.0	9.97 b[†]	9.37 a	0.92	0.87
30-20-30-20	16.3	15.0	69.3	62.3	10.50 b	9.39 a	0.94	0.87
30-30-40-0	17.0	15.0	70.0	56.7	12.30 a	9.26 a	0.95	0.88
50-20-20-10	17.0	14.7	65.3	57.0	9.71 b	9.32 a	0.96	0.91
70-0-20-10	17.0	14.7	66.7	58.7	9.82 b	9.41 a	0.91	0.89
100-0-0-0	16.3	14.0	61.0	56.3	9.64 b	8.88 b	0.88	0.81
F-value Cultivar	64.80**		30.27**		20.45**		9.24**	
F-value N split application	1.40 ns		2.40 ns		3.46*		1.80 ns	
F-value Interaction	0.48 ns		2.07 ns		3.14*		0.21 ns	

[†]Means followed by a common letter in a column are not significantly different at the 5% level by DMRT.
*,**means are significantly different at 5% and 1% level, respectively.

Table 4. Yield and yield components as affected by split application of nitrogen.

Split application treatments (%)	Panicle (no./m^2)		Spikelet (no./panicle)		Fertility (%)		1000 grain weight		Grain yield (ton/ha)	
	IR58	Shinunbongbyeo	IR58	Shinunbongbyeo	IR58	Shinunbongbyeo	IR58	Shinunbongbyeo	IR58	Shinunbongbyeo
25-25-25-25	356.0 d[†]	342.0 d	77.5 a	71.8 a	89.3 a	91.2 a	24.3 c	24.8 b	5.13 ab	4.51 b
30-20-30-20	352.0 d	349.3 d	76.3 a	72.3 a	88.1 a	90.1 ab	24.4 bc	24.8 b	5.13 ab	4.68 ab
30-30-40-0	370.0 cd	364.3 cd	81.9 a	76.1 a	85.6 ab	89.0 ab	24.1 c	24.5 bc	5.41 ab	5.06 a
50-20-20-10	390.7 bc	383.7 bc	82.2 a	76.4 a	87.8 a	87.9 ab	25.0 a	25.5 a	5.46 ab	5.12 a
70-0-20-10	406.7 ab	403.7 ab	79.9 a	72.7 a	87.7 a	88.9 ab	25.4 a	25.4 a	5.56 a	5.08 a
100-0-0-0	422.0 a	419.0 a	70.0 b	64.4 b	82.3 b	86.4 b	24.1 c	24.1 c	5.04 b	4.74 ab
F-value Cultivar	1.47 ns		28.39**		9.07**		31.68**		21.41**	
F-value N split application	22.87**		11.45**		5.31**		23.57**		4.16**	
F-value Interaction	0.12 ns		0.15 ns		0.72 ns		0.16 ns		0.29 ns	

[†]Means followed by a common letter in a column are not significantly different at the 5% level by DMRT.
**means are significantly different at 1% level.

5.12 t/ha in IR58 and Shinunbongbyeo, respectively. Panicle number was significantly different among the N split application in both cultivars. It was highest at 100-0-0-0 and least at 25-25-25-25 and 30-20-30-20 where basal fertilizer was low. These results agree with Matsushima (1980) who reported that panicle number was increased through the application of high dose of basal fertilizer. High grain yields were obtain in relatively high panicle number but not the highest. Number of spikelets was highest at 30-30-40-0 and 50-20-20-10. However, there was no significant difference among the treatments except at 100-0-0-0 which is all basal. The response pattern was similar in both cultivars but IR58 had higher panicle number and spikelet number per panicle than Shinunbongbyeo. It can be inferred that spikelet number responds more to N applied at necknode differentiation stage. Basal application of N alone can limit the formation of spikelets as well as the other yield components. Matsushima (1980) reported that the period between necknode differentiation stage and just before the reduction division stage was the most effective time to top dress to increase the number of spikelets per panicle. The negative association between panicle number and spikelet number per panicle when N was optimum was also reported by chang et al. (1986). The highest spikelet fertility was found at treatment 25-25-25-25, where high N was applied at heading. Shinunbongbyeo had slightly higher spikelet fertility than IR58. High basal fertilizer enhanced the number of panicle per m^2, while the percent fertility was diminished. Matsushima (1980) reported similar response from basal N application. The weight of 1000 grains significantly increased with split application of N in contrast to the basal application. The responses was best at 50-20-20-10 where basal N was mod-

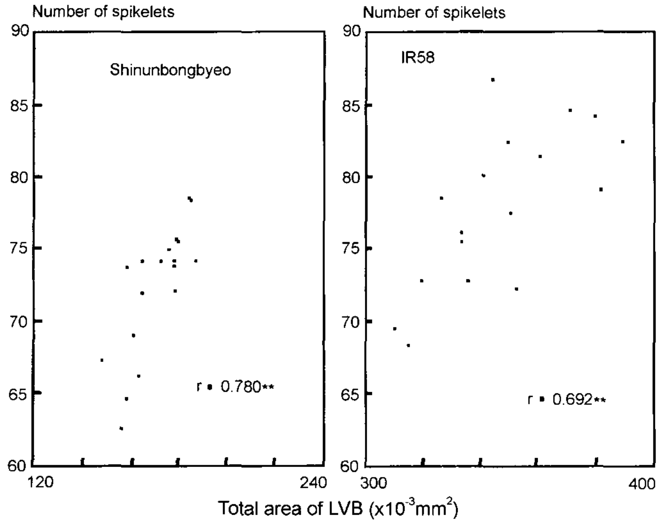

Fig. 1. Relatoinship between the total area of large vascular bundle (LVB) in the peduncle and the number of spikelets.

erate and N was also applied at heading. These findings generally agree with Matsushima (1980) who found topdressing applied just before the reduction division stage was most effective in increasing grain weight. The results indicated that N split application at the heading stage has a favorable effect on the 1000 grains weight. Split application of N resulted in: 1) increased number of panicle with more N basally applied, 2) increased spikelets number with N application at necknode differentiation stage, and 3) increased spiketet fertility and 1000 grain weight with N applied at neckyoke differentiation and heading stage.

The total cross sectional area of LVB in peduncle closely correlated with the number of spikelets per panicle (Fig. 1). This findings implied that higher total cross sectional area of LVB in peduncle can be produced more spikelet number.

Manipulation of N management in early growth stage might induce better VB development in rice which might eventually be translated into more and bigger VB in the panicle. This may result in more primary branches and higher number of spikelets and high grain weight. Improving spikelet filling through better VB can increase yield potential of rice cultivars.

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