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Root Growth and Nutrient Uptake of Rice as Affected by Planting Methods and Green Manures

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ABSTRACT

Field experiment with rice was conducted at IRRI during 1989 wet season. The experimental design was a two-factor randomized complete block with 12 treatments and four replications. Fertilizer N was applied at 60 kg N/ha as 2/3 basal incorporated (B&I) + 1/3 N topdressed at 5-7 days before panicle initiation (DBPI) except for pure green manure treatments where the full N dose as *Sesbania rostrata* (*Sesbania*) or *Aeschynomene afraspera* (*Aeschynomene*) was basally incorporated. Root length density was determined at the flowering and plant nutrient uptake was determined separately by calculating from the product of dry matter, straw dry weight, grain yield and % N, P, K content. Results showed that root growth of broadcast seeded flooded rice (BSFR) was higher at all soil depth than transplanted rice (TPR) as per unit area due to higher plant density and root growth was not disturbed by uprooting. However, on a per tiller basis, root length was significantly lower in BSFR than in TPR at 0-10 cm soil depth which could have partly caused more lodging in BSFR. There were no significant differences among N treatments and no interaction between planting method and N treatment on root growth. However, nonfertilized control gave significantly higher root-to-shoot ratio than did N-treated plots. Total N uptake in BSFR was higher than that in TPR. Topdressing urea in PU-green manure treatments resulted in higher N uptake at maturity than did green manure applied alone. Phosphorus and K uptake were not significantly differ among the fertilized treatments in both TPR and BSFR at 5-7 DBPI.

Key words : root growth, nutrient uptake, green manure, planting method, rice

INTRODUCTION

Root growth is affected by planting conditions, mainly because transplanting would damage root system and puddling operation prior to transplanting will tend to form hard pan and increase the soil's water retention capacity (Sharma and De Datta, 1986). Application of green manure results in improving the soil physical environment and thus, may affect root growth and nutrient uptake of rice plant.

A field study was therefore conducted to investigate the effect of planting method and green manure on the root development and nutrient uptake of lowland rice.

MATERIALS AND METHODS

A field experiment was established on Maahas clay at the International Rice Research Institute (IRRI), Philippines, during 1989 wet season, using a two-factor factorial randomized complete block design with four replications. Table 1 show the soil properties of the experimental site. Treatments were combinations of two planting methods (TPR and BSFR) and six N sources (No fertilizer N, Prilled urea (PU), all *Sesbania*, 2/3 *Sesbania* + 1/3 PU, all *Aeschynomene*, 2/3 *Aeschynomene* + 1/3 PU). Plot size was 3 x 5.5 m. *Sesbania* or *Aeschynomene* was applied alone or in combination with prilled urea (PU). No fertilizer N and mineral N as PU were the control treatments. Fertilizer N was applied at 60 kg N/ha as 2/3 B&I + 1/3 N topdressed at 5-7 DBPI except for pure green manure treatments where the full N dose was basally incorporated. Phosphorus (0-46-0) and K (0-0-60) at 30 kg/ha each were applied together with the first N dose. *Sesbania* and *Aeschynomene* were grown in the field outside the trial area and harvested at 45 days after emergence (DAE). Table 2 shows the selected chemical properties of green manure plants. One day before broadcast seeding or transplanting (IR72), the green manure crop was harvested, weighed, transferred to the trial area and chopped into 2-3 cm long

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before incorporation. Green manure crop was applied as a fresh material and incorporated into the soil using power weeders. Broadcast seeding and transplanting were done on the same day in uniformly leveled plots. For BSFR, pregerminated seeds were sown evenly at 100 kg seeds/ha (dry weight) by hand without stepping into the plots. For TPR, 20-day-old seedlings were hand transplanted on 20 x 20 cm spacing at 3-4 seedlings/hill.

To compare the rooting behavior between BSFR and TPR and between green manure treatments, root length density was determined at flowering. Roots and plants in BSFR were sampled using a metal root sampler (20 x 20 x 50 cm) described by Thangaraj and O'Toole (1986) up to 40 cm depth. The soil was sectioned into 0-10, 10-20, 20-30 and 30-40 cm layers (Sharma et al., 1987). In TPR, soil sampler was placed directly over the center of one rice hill, thereby sampling a representative area for the 20 x 20 cm transplant spacing. Each soil section was contained in a plastic bag, soaked for about 24 hours in Calgon solution, as proposed by Thangaraj and O'Toole (1986), to break the soil aggregates. Thereafter, the soil on a screen wire was washed with tap water to obtain the roots.

Root length was determined using a Comair Root Length Scanner (Commonwealth Aircraft, Australia). Total root length (m), total root dry weight (g), root length/tiller, and root length density in root length per unit soil volume (cm/cm^3 soil) were obtained. Root and plant samples were dried at 70° C for three days, then weighed to obtain the root-to-shoot ratio. Total N, P, K, content (%) of the plant and root samples were then measured.

Nitrogen, P and K uptake by plant, grain and straw were determined separately by calculating from the product of dry matter, straw dry weight, grain yield and percent N, P, K content. Dry matter production and plant N, P and K accumulation were determined at 5-7 DBPI, flowering and crop maturity. The sampling areas were obtained using the procedures described by Gomez (1972).

Table 1 Soil properties of the experimental site.

Soil properties	0-15 cm	15-30 cm
Ph (1:1 w/v H_2O)	6.4	6.6
Organic C (%)	2.26	1.17
Total N (%)	0.21	0.09
CEC* (meq/100g)	42	44
Exch. K (meq/100g)	1.17	0.87
Exch. Mg (meq/100g)	16.9	16.7
Exch. Ca (meq/100g)	23.7	25.3
Exch. Na (meq/100g)	1.60	1.55
Olsen P (ppm)	nil	nil
Available Zn (ppm)	0.24	0.10
Clay (%)	67	72
Silt (%)	28	25
Sand (%)	5	5
Soil texture	Clay	
Soil series	Maahas	
Soil taxonomy	Fine clayey, mixed, isohyperthermic Andaqueptic Haplaquoll	

* CEC = cation exchange capacity

Table 2 Chemical analysis of *Sesbania rostrata* and *Aeschynomene afraspera* at 45 days after emergence grown under field conditions.

Properties	*Sesbania rostrata*	*Aeschynomene afraspera*
N (%)	2.90	3.10
P (%)	0.25	0.30
K (%)	2.22	2.42
Mg (%)	0.15	0.35
Ca (%)	0.82	0.71
Zn (ppm)	19	27
C (%)	44	37
C/N ratio	15	12
Lignin (%)	8.6	8.4

RESULTS AND DISCUSSION

Figure 1 shows the meteorological data at the experimental site over a ten-year period, from 1979 to 1988, and in 1989.

Root Growth

Root growth and development is important in BSFR. Poor root growth after seeding may cause rice seeds to float, uneven distribution, poor stand establishment and eventually reduced grain yield. Total root length and total root dry weight were affected by planting method. Broadcast seeded flooded IR72 gave significantly higher total root length and root dry weight than did TPR (Table 3 and Figure 2). However, length of root per tiller was lower in BSFR than in TPR at 0-10 cm soil depth (Figure 2). This probably caused

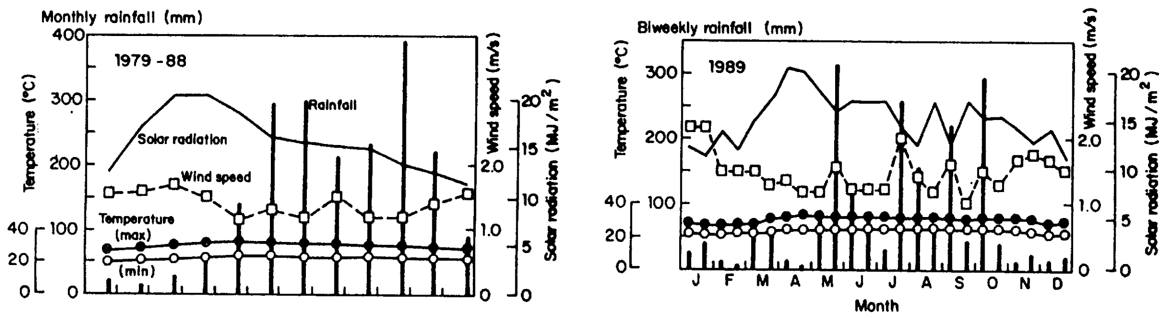

Figure 1 Average monthly meteorological data at the experimental site for 10 years (1979-1988) and average bi weekly data in 1989.

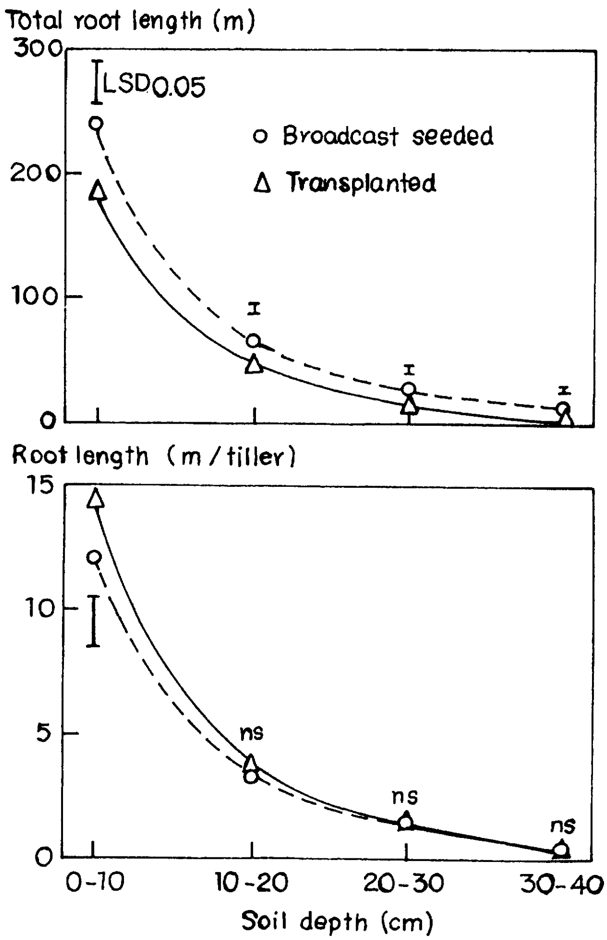

Figure 2 Effect of planting method on total root length and root length per tiller of IR72 at flowering stage (ns = not significant).

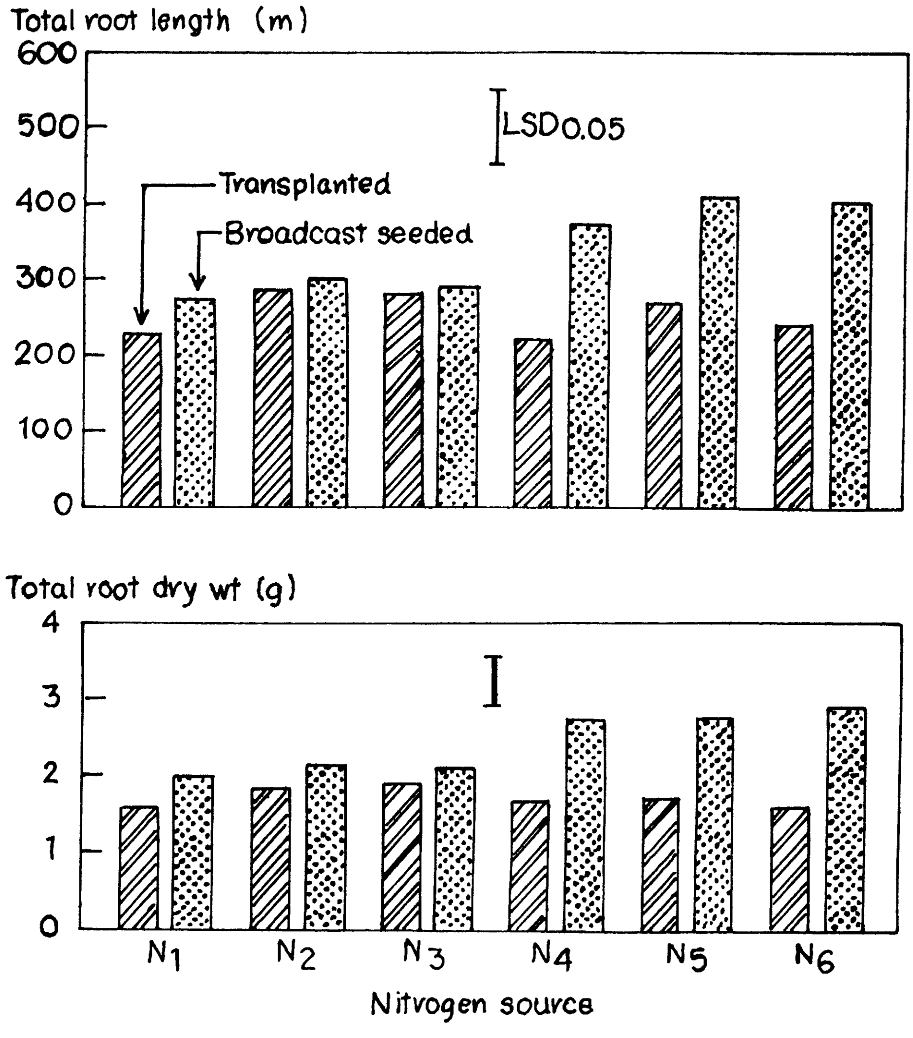

Figure 3 Total root length and total root dry weight of transplanted and broadcast seeded flooded IR72 at flowering stage as affected by different N sources.

N1 = no fertilizer N
N2 = PU
N3 = All *Sesbania*
N4 = 2/3 *Sesbania* + 1/3 PU
N5 = All *Aeschynomene*
N6 = 2/3 *Aeschynomene* + 1/3 PU

Table 3 Total root length, total root dry weight and root-to-shoot ratio of IR72 at flowering stage as affected by planting methods and N sources [a]

Treatment	Total root length (m)	Total root dry weight (g)	Root-shoot ratio
Planting method (P)			
TPR	258	1.7	0.06
BSFR	344	2.4	0.07
$LDS_{0.05}$	40	0.3	ns
N source (N)			
No ferlitizer N	245	1.8	0.08
Prilled urea (PU)	297	2.0	0.05
All *Sesbania*	291	2.0	0.07
2/3 *Sesbania*+ 1/3PU	341	2.3	0.05
All *Aeschynomene*	341	2.3	0.08
2/3 *Aeschynomene*+ 1/3PU	325	2.3	0.07
$LSD_{0.05}$	ns	ns	0.02
Interaction			
PXN	ns	ns	ns

[a] Average over 4 replications. ns = not significant

more lodging in BSFR than in TPR, although no lodging was observed in this experiment. No significant difference among N treatments and no interaction between planting method and N treatment were observed (Table 3 and Figure 3).

Root-to-shoot ratio is the weight of root fraction (g) 40 cm below the soil surface per 1 g of rice shoot. A significant difference in the root-to-shoot ratio was recorded among the N treatments. Nonfertilized control gave the highest root-to-shoot ratio whereas PU applied alone or *Sesbania*-PU combination gave the lowest (Figure 4). However, planting method did not affect root-to-shoot ratio. These results were in contrast to those reported by Katare and Upadhyay (1981), who found that root-to-shoot ratios were wider with direct seeding than that with transplanting method.

Rice is often described as a shallow-rooted crop. One remarkable characteristic of the root system is the high root densities in surface soil (Yoshida and Hasegawa, 1982). Planting method significantly affected the root length density of IR72 at flowering stage. BSFR gave higher root length density at all soil depths than did TPR (Figure 5). Root length density was not significantly affected by N treatments at 0-10, 10-20, 20-30 cm soil depths but was affected at 30-40

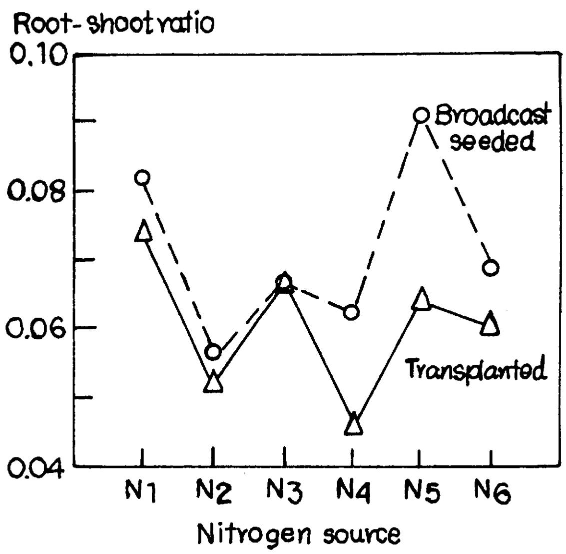

Figure 4 Root-shoot ratio of transplanted and broadcast seeded flooded IR72 at flowering stage as effected by different N sources.

N1 = no fertilizer **N4 = 2/3 Sesbania + 1/3 PU**
N2 = PU **N5 = All Aeschynomene**
N3 = All Sesbania **N6 = 2/3 Aeschynomene + 1/3 PU**

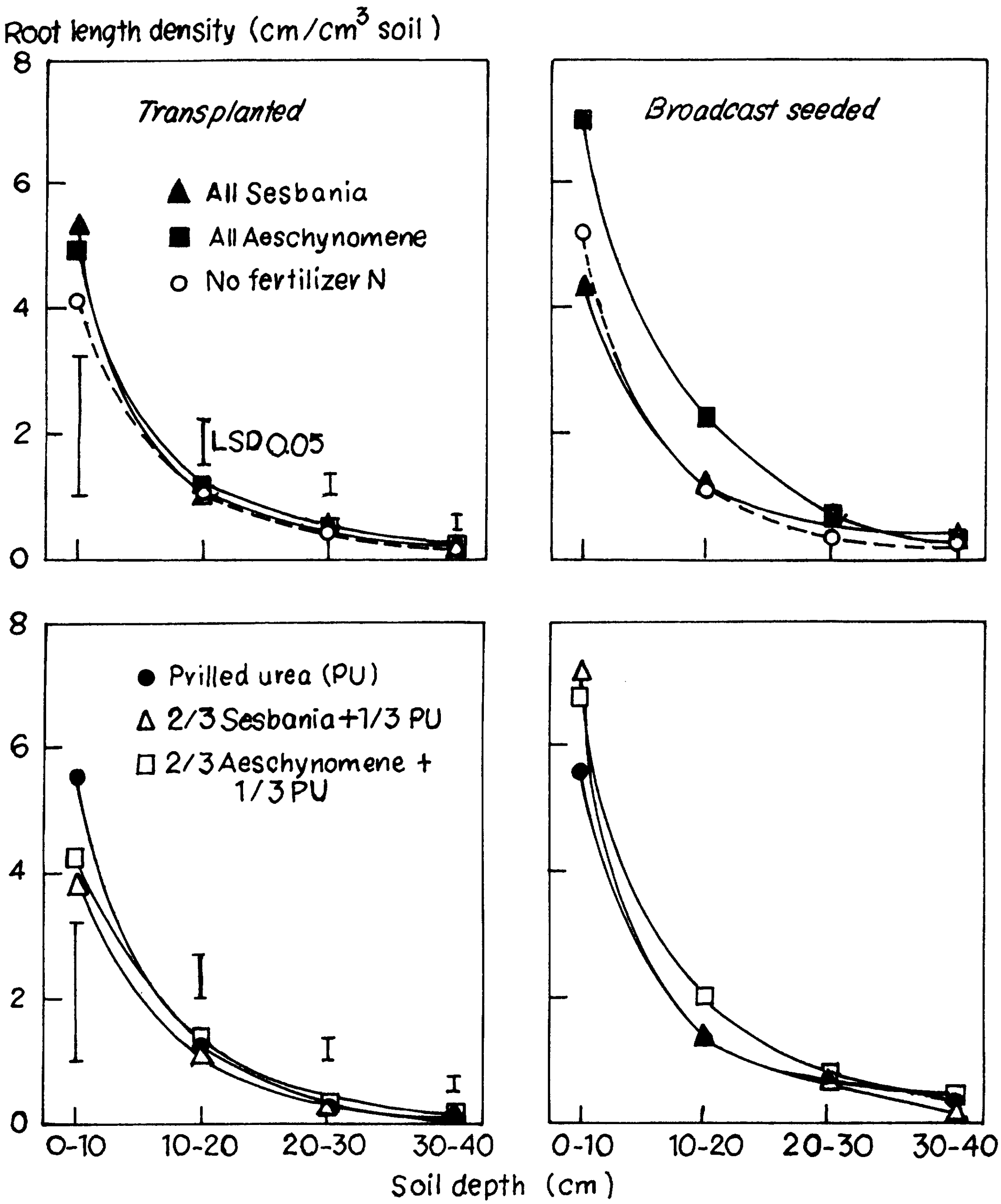

Figure 5 Root length density of transplanted and broadcast seeded flooded IR72 at flowering stage as affected by different N sources.

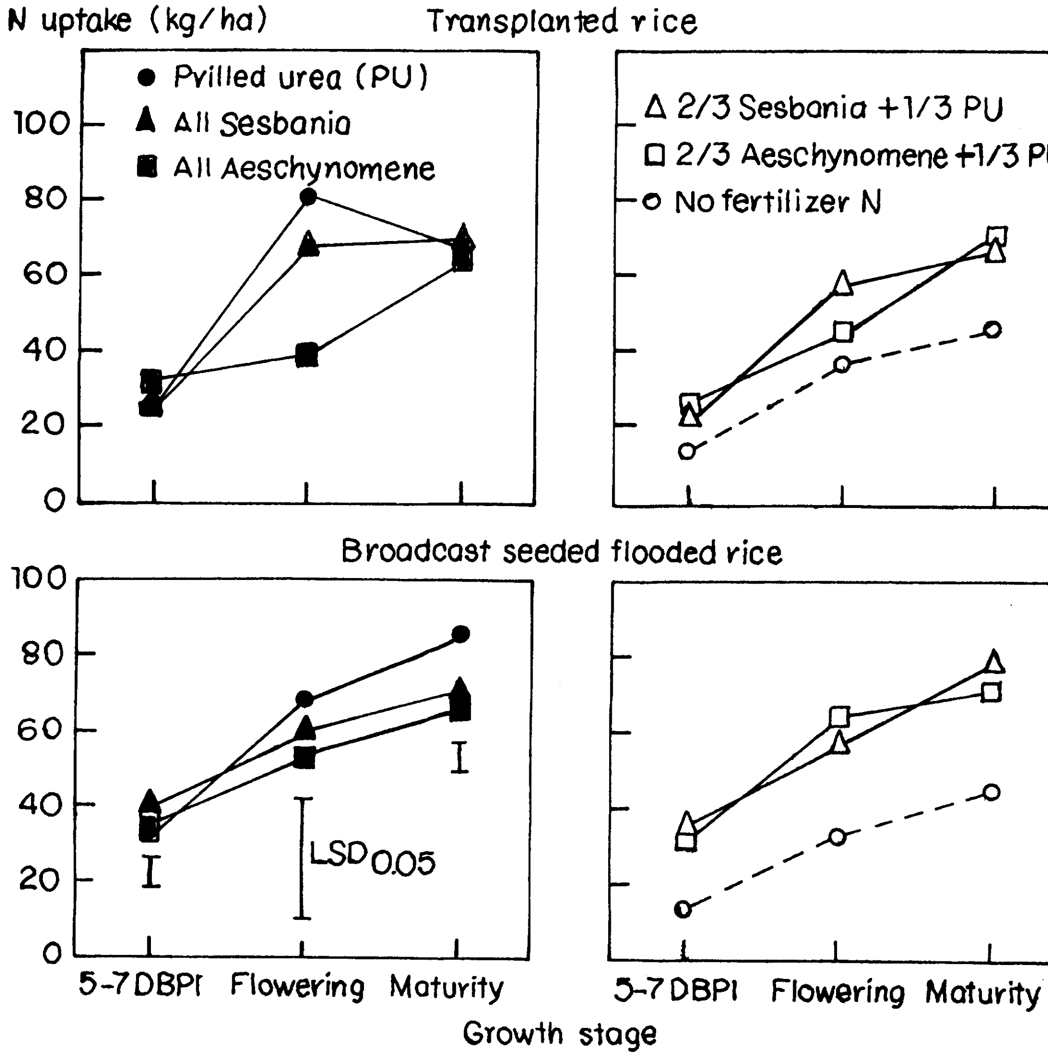

Figure 6 Plant N uptake of transplanted and broadcast seeded flooded IR72 as affected by green manure and urea amendment.

DBPI = days before panicle initiation. LSD bars are represented for all figures.

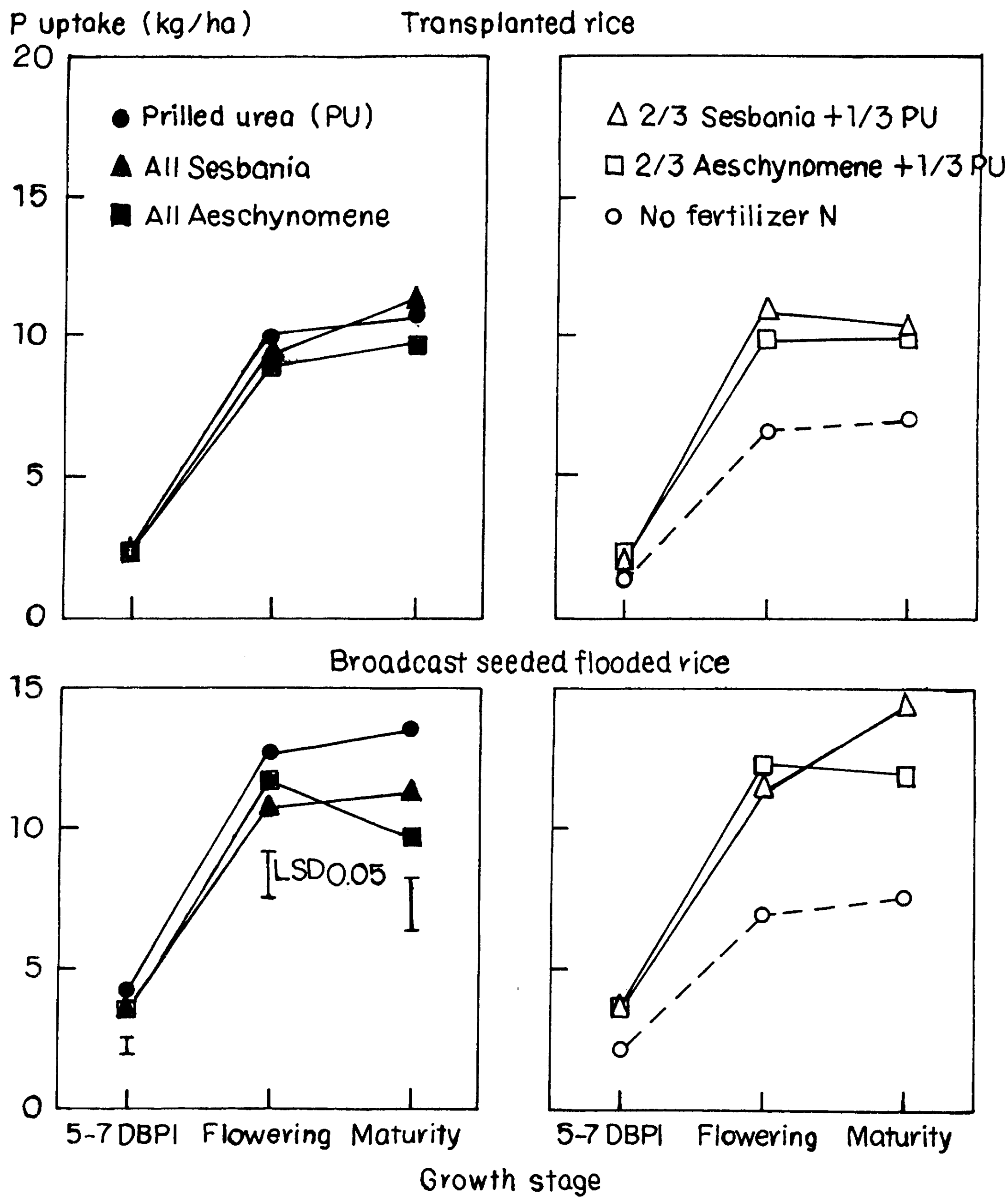

Figure 7 **Plant P uptake of transplanted and broadcast seeded flooded IR72 as affected by green manure and urea amendment.**

DBPI = days before panicle initiation. LSD bars are represented for all figures.

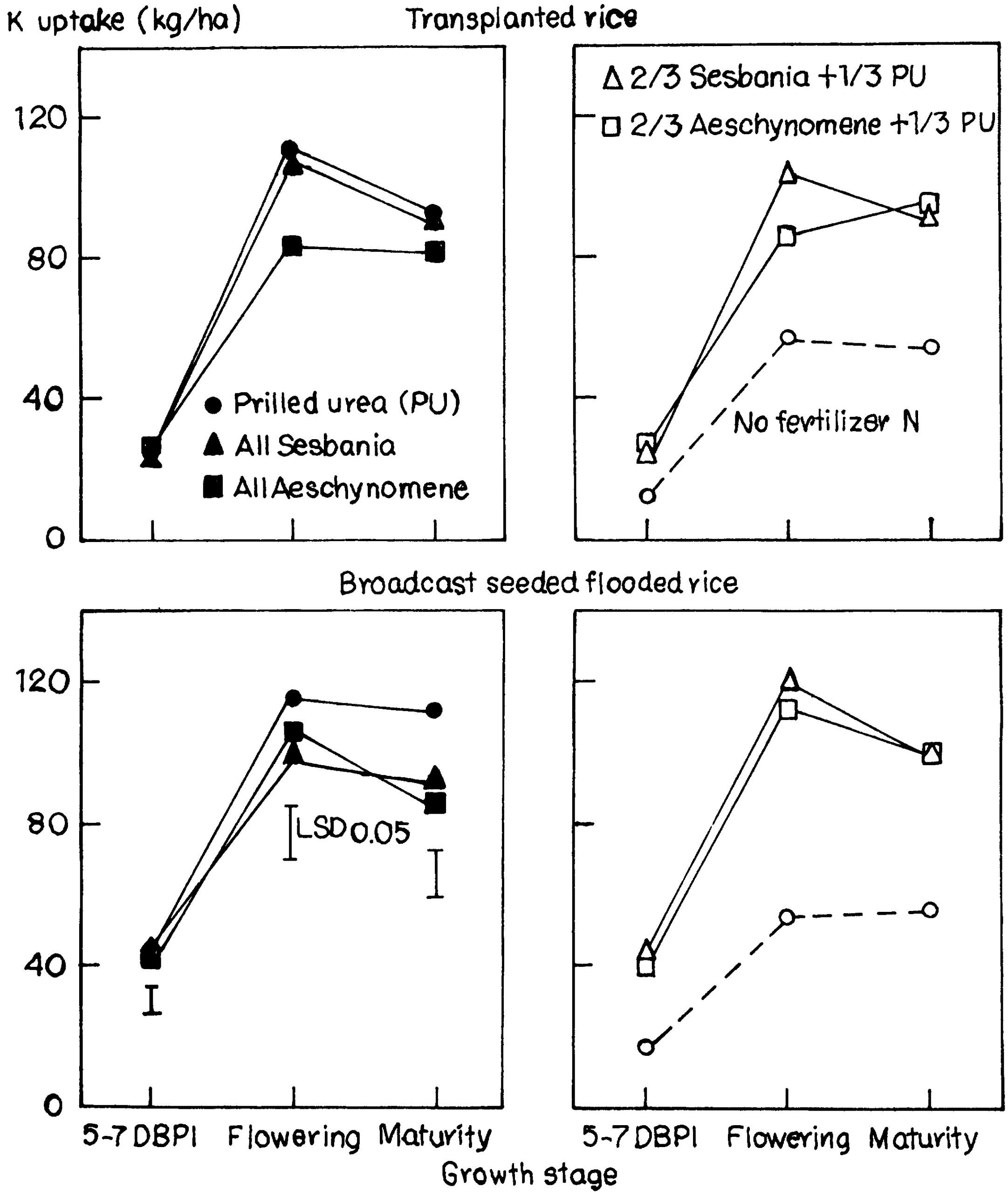

Figure 8 **Plant K uptake of transplanted and broadcast seeded flooded IR72 as affected by green manure and urea amendment.**

DBPI = days before panicle initiation. LSD bars are represented for all figures.

Table 4 Plant N uptake of IR72 at maturity as affected by green manure and urea amendment [a]

N Source	N Uptake (kg/ha) Grain	Straw	Total
	Transplanted rice		
No fertilizer N	26	21	47
Prilled urea (PU)	38	30	68
All *Sesbania*	37	33	70
2/3 *Sesbania* + 1/3 PU	40	29	69
All *Aeschynomene*	36	29	65
2/3 *Aschynomene* + 1/3 PU	39	34	73
	Broadcast seeded flooded rice		
No fertilizer N	25	21	46
Prilled urea (PU)	42	44	86
All *Sesbania*	35	36	71
2/3 *Sesbania* + 1/3 PU	41	39	80
All *Aeschynomene*	33	34	67
2/3 *Aeschynomene* + 1/3 PU	39	35	74
$LSD_{0.05}$	4	6	
CV (%)	8	12	

[a] Average over 4 replications.

cm soil depth. In general, higher root length density was found at the 0-10 and 10-20 cm soil depths. Similar results were obtained by Yoshida and Hasegawa 1982) and Sharma *et al.* (1987).

Nutrient Uptake

Nitrogen uptake data are summarized in table 3 and Figure 5. At an equal N rate, N uptake at 5-7 DBPI and flowering stage was higher with fertilizer N added than in nonfertilized control in both planting methods. However, N uptake was not significantly different among fertilizer N added treatments. At crop maturity, total N uptake by plant for nonfertilized control ranged from 46 to 47 kg/ha (Table 4). With fertilizer N added, total N uptake by plant ranged from 65 kg/ha in TPR with *Aeschynomene* applied alone to 86 kg/ha with urea applied alone in BSFR. Plant N decreased between flowering and crop maturity with urea applied alone in TPR (Figure 6). No such decrease in plant N after flowering suggest postflowering gaseous loss of plant N (Wetselaar and Farquhar, 1980).

Total N uptake in BSFR was generally higher than that in TPR during vegetative and reproductive stages (Figure 6). This was due to transplanting shock, lower plant density and higher N losses in TPR. Topdressing urea in PU-green manure treatments resulted in higher N uptake at maturity than that in treatments with green manure applied alone (Table 4).

Phosphorus uptake increased at 5-7 DBPI up to flowering and declined thereafter (Figure 7). Phosphorus uptake was not significantly different among the green manure treatment in both TPR and BSFR at 5-7 DBPI and flowering stages.

In BSFR at maturity, applying green manure+ PU gave higher P uptake than did green manure applying than did green manure applied alone (Figure 7). This could be due to greater dry matter accumulation when PU was topdressed. However, Mamaril *et al.* (1986) reported that P uptake was not significantly different among the green manure treatments at 30 days after transplanting and at harvest.

Potassium uptake increased up to flowering stage and declined at crop maturity in all treatments except with 2/3 *Aeschynomene* + 1/3 PU in TPR (Figure 8). However, K uptake did not significantly differ among green manure treatments with or without PU at 5-7 DBPI and at crop maturity

CONCLUSION

Planting method significantly affected the root length density of IR72 at flowering stage. BSFR gave significantly higher total root length, root dry weight and root length density at all soil depths than did TPR due to higher plant density and root growth was not damaged by uprooting unlike that of in TPR where seedlings were pulled. However, on a per tiller basis, root length was significantly higher in TPR than in BSFR at 0-10 cm soil depth. There were no significant differences among N treatments on root growth. But nonfertilized control gave significantly higher root-to-shoot ratio than did fertilized plots.

Total N uptake in BSFR was higher than that in TPR during various plant growth stages. Topdressing urea in PU-green manure treatments resulted in higher N uptake at maturity than that in treatments with green manure applied alone. Phosphorus and K uptake were not significantly different among the green manure treatments with or without PU in both TPR and BSFR at 5-7 DBPI.

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