

Integrated Nutrient Management in Broadcast Seeded Flooded Tropical Rice

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Increased irrigated areas, the availability of short-duration modern rice and cost - efficient herbicides, and high labor costs have motivated many irrigated and favorable rainfed rice farmers in Southeast Asia to shift from transplanting to direct seeding. Information on fate of N, however, is limited. A field experiment was conducted to evaluate efficient N management in broadcast seeded flooded rice (BSFR). Combined applications of green manure (*Sesbania rostrata* or *Aeschynomene afraaspera*) and prilled urea substantially reduced N losses by NH_3 volatilization. Floodwater data, such as partial pressure of NH_3 (pNH_3) showed that *Sesbania rostrata* and *Aeschynomene afraaspera* have the potential to minimize N losses. Exchangeable NH_4^+ -N in the soil was depleted from 21 days after N application. Transplanted rice (TPR) gave relatively higher NH_4^+ -N concentration in the soil during the first 21 days after N application than did BSFR. Broadcast seeded flooded rice depleted NH_4^+ -N sources faster than did TPR due to vigorous early growth in BSFR caused by higher plant density and absence of "transplanting shock". However, both planting methods gave similar rice grain yield. Green manure - prilled urea combinations gave grain yields similar to that with prilled urea applied alone but were significantly higher than that with green manure applied alone. *Sesbania rostrata* applied alone as N source generally gave slightly higher grain yield than did *Aeschynomene afraaspera*.

Keywords : broadcast seeded flooded rice, prilled urea, green manure, *Sesbania rostrata*, *Aeschynomene afraaspera*

Although transplanting is the most popular method of crop establishment in lowland rice in tropical Asia, broadcast seeding of pregerminated rice onto mud has become an important stand establishment technique (De Datta, 1986; Singh and Misra, 1987). Improved water control techniques, better availability of inexpensive herbicides, release of modern rice varieties which are high yielding, fast emerging and early maturing, and labor saving bias have encouraged many farmers in tropical Asian countries to switch from the traditional transplanted

to the less expensive broadcast seeded flooded rice

The concept of integrated nutrient management seeks to sustain soil fertility through an integration of different available nutrient sources and their application methods that will produce maximum crop yield with minimum input use. This concept is concerned not only with the continued use of inorganic and organic fertilizers but also with other efforts to increase the efficiency of inorganic and organic fertilizer use. Recently interest in green manure has revived because of increased fertilizer

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prices in relation to rice prices, increased concern for maintaining long-term soil productivity and ecological sustainability (Ladha *et al.*, 1988). Green manure crops can improve soil properties as well as conserve and recycle nutrient. Potentially, green manure species are N sources with relatively high use efficiency. At present, the worldwide integrated use of green manure and inorganic N is receiving much attention in the search for alternative strategies to maximize N use efficiency in lowland rice (Chungchu, 1988; Kulkarni and Pandey, 1988; Roy *et al.*, 1988; De Datta, 1989; De Datta and Buresh, 1989).

Among the green manures, the two stem - nodulating legumes (*Sesbania rostrata* and *Aeschynomene afraspera*) are receiving increased attention in view of their potential high atmospheric -N₂ fixing ability and wide adaptability. These legumes produce nodules on both root and stem and grow in flooded as well as dry conditions (Dreyfus *et al.*, 1988). They have been reported to show fast growth and high N accumulation. Stem - nodulating ability provides an additional opportunity to fix N under flooded conditions (Alazard and Becker 1987; Meelu and Morris, 1988), hence, are promising N sources for lowland rice. However, due to photosensitivity, the use of these species is limited during the short - day period.

Under the present resource - scarce situation, the integrated use of green manure and mineral N is receiving much attention in the hope of meeting the farmers' economic needs as well as the ecological demand. Field experiments, which revealed the management of green manure N in lowland rice ecosystem, have been conducted with transplanted rice (Mamaril *et al.*, 1986, Morris *et al.*, 1986; Biswas, 1988). More information on N release and N availability, and loss mechanisms of green manure in broadcast seeded flooded rice are essential to develop alternative strategies to maximize N use efficiency.

Materials and Methods

The field experiment was conducted on Maahas clay (fine clayey, mixed, isohyperthermic Andaqueptic haplaquoll) at the International Rice Research Institute (IRRI), Philippines. Table 1 shows the soil properties of the experimental site.

The response of broadcast seeded flooded (BSFR) and of transplanted (TPR) lowland IR72 rice to prilled urea (PU), *Sesbania rostrata* (*Sesbania*) and *Aeschynomene afraspera* (*Aeschynomene*) amendment as N source, applied alone or in combination, were compared. The experimental design was a two - factor factorial randomized complete block with four replications. Treatments were combination of two planting methods and six N sources. Plot size was 16.5 m² (3.0 x 5.5 m)

Table 1. Soil properties of the experimental site.

Soil properties	0-15 cm	15-30 cm
pH (1:1 w/v H ₂ O)	6.4	6.6
Organic C (%)	2.26	1.17
Total N (%)	0.21	0.09
CEC ^o (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	

^oCEC = cation exchange capacity.

Sesbania or *Aeschynomene* was applied alone or in combination with 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 N 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* or *Aeschynomene* was basally incorporated. Phosphorus and K at 30 kg/ha each were applied together with the first N dose.

The *Sesbania* and *Aeschynomene* were grown in the field outside the trial area and harvested at 45 days after emergence (DAE). Green manure plants received 20 kg P/ha and 20 kg K/ha as basal dose. Two days before harvest, some green manure plants were sampled and analyzed for total N (semi - micro kjeldahl method) and dry matter content. Lignin content of plants was determined using the acid-detergent method of Van Soest (1984) with a Fibertec system M1020/1021 (Tecator, Hoegenaes, Sweden). Total C was determined by using dry combustion in a Perkin Elmer - M240 autoanalyzer following the procedure of Culmo (1969). The rest of the samples was analyzed by the Analytical Service Laboratory (ASL) of IRRI. Table 2 shows the selected chemical properties of green manure plants.

One day before broadcast seeding or trans-planting rice, the green manure crop was harvested, weighed, transferred to the trial area and chopped 2-3 cm long before incorporation. Green manure was applied as a fresh material and incorporated into the soil using power weeder.

Broadcast seeding (after subjected to water for 24 hours and incubated for 48 hours) and transplanting were done on the same day in uniformly leveled plots. For TPR, 20 - day - old seedlings were hand - transplanted on 20 x 20 cm spacing at 3 - 4 seedlings/hill.

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

Properties	<i>Sesbania rostrata</i>	<i>Aeschynomene afraspera</i>
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

For BSFR, pregerminated seeds were sown evenly on leveled plots at 100 kg/ha (dry weight) by hand without stepping into the plots.

Fertilizer N was B&I into the soil without standing water. In BSFR plots, water was introduced at 4 days after seeding (DAS) with 2 cm standing water up to 7 DAS, then floodwater depth was gradually increased to 5 cm. In TPR plots, floodwater was introduced at 1 day after fertilizer application and maintained at 5 - cm depth throughout the growing season.

The kinetics of exchangeable NH_4^+ -N were monitored after basal incorporation of fertilizer N. Soils from 0 - to 20 - cm depth were sampled weekly up to flowering, biweekly thereafter up to crop maturity using a core sampler by Sharma and De Datta (1985). Soils from four sampling locations/plot were combined, thoroughly mixed and subsampled for extraction and moisture determination. From the subsamples, 50 g of soil was taken for moisture determination. Eighty g of fresh soil was weighed in a 250 - ml plastic bottle with addition 100 ml of 2 M KCl and shaken for 1 hour. The soil solution was filtered through Whatman No.42 filter paper in Buchner

funnel and flask attached to a vacuum. The soil was washed with 100 ml of 2 M KCl and the filtrate was transferred to a 250 ml volumetric flask and made up to volume with the same extracting solution. The extract was analyzed for exchangeable NH_4^+ -N in the autoanalyzer by colorimetric method.

Floodwater samples of about 200 ml were collected at 1300-1400 hours from 1 to 7 days after fertilizer application. *In situ* measurements of floodwater pH, temperature and water depth were taken simultaneously with floodwater sampling. Samples were immediately shaken and filtered through Whatman No.5 filter paper in the laboratory. Filtered sample (18-ml) was treated with 2 ml of 50 ppm phenylmercuric acetate (50 ppm PMA) to inhibit urease activity. Samples were colorimetrically analyzed for NH_4^+ -N by TAA II Industrial Method, 1977. Partial pressure of ammonia (pNH_3) in the floodwater was computed based on ammoniacal N concentration, pH and temperature using the corrected equation of Denmead *et al.* (1982, 1983).

Rice plants were sampled to determine dry matter and leaf area index (LAI). Plant sample size was 8 hills/plot in TPR and plants were sampled from two 40 × 40 cm area in BSFR. Leaf area (cm^2) was measured using a leaf area meter (Model AAM - 7, Hayashi Denko, Japan). Plant samples were cut at soil surface level. Base of plants was washed thoroughly with tap water followed by distilled water to remove soil particles. Tissue dry matter was determined after oven-dry at 70 °C to constant weight. Grain and straw yield of BSFR was determined from a 5- m^2 area at the center of each plot. Plant from two 0.16- m^2 area were harvested for yield components. Spikelet number per panicle, percent unfilled spikelet and 100 grain weight were recorded from 10 sample panicles. In TPR, 125 hills were harvested for grain and straw yield. Eight hills were harvested for yield component. Grain yield was expressed at 14% moisture

content in t/ha. Harvest index (HI) was derived from the ratio of rough rice (grain yield) to total above ground biomass production (biological yield).

Results and Discussion

Kinetics of Exchangeable Ammonium-N

Ammonium-N depletion was slightly faster in BSFR than in TPR presumably due to more rapid uptake in BSFR than in TPR (Figure 1). Ammonium-N concentration for all treatments declined sharply from 21 days after N application and remained at a low level thereafter. Release of NH_4^+ -N from PU applied alone was faster than that with green manure because green manure still had to undergo decomposition.

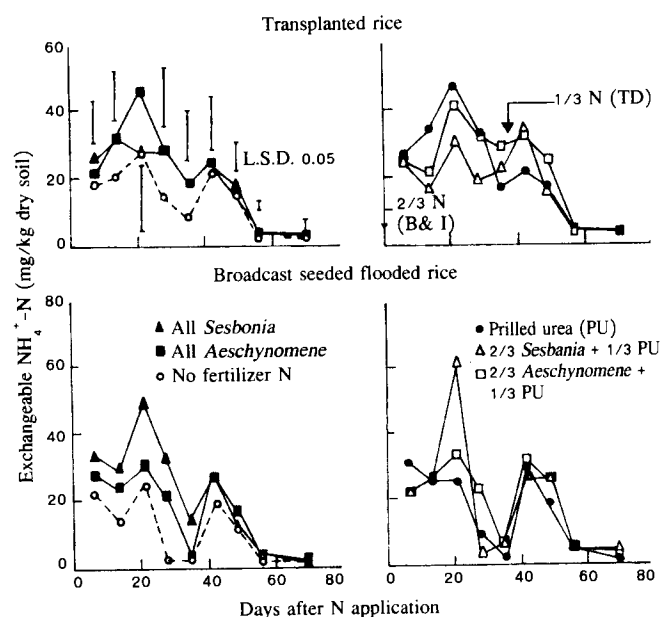


Figure 1. Kinetics of exchangeable NH_4^+ -N in the soil as affected by green manure and urea amendment. LSD bars are represented for all figures. B & I = broadcast and incorporated, TD = topdressed.

The rapid decline in exchangeable NH_4^+ -N, even after topdressing 1/3 N as PU at 5-7 days before panicle initiation, was attributed to rapid plant N uptake. Nitrogen levels in TPR trial after fertilizer application

were considerably higher than in BSFR trial because BSFR used more N than did TPR. Since TPR suffered from "transplanting shock", its dry matter production and plant N uptake were lower during the first 21 days after N application than that of BSFR. Then, exchangeable NH_4^+ -N depletion by plant uptake was delayed. Also, high growth rate and high density in BSFR during early vegetative stage resulted in faster NH_4^+ -N depletion than that in TPR.

Floodwater Properties

Floodwater temperatures ranged from 28 to 39°C (Figure 2). High floodwater temperature combined with high floodwater pH after fertilizer application creates a favorable environment for NH_3 volatilization loss (Vlek and Craswell, 1981; Beutier and Renon, 1978).

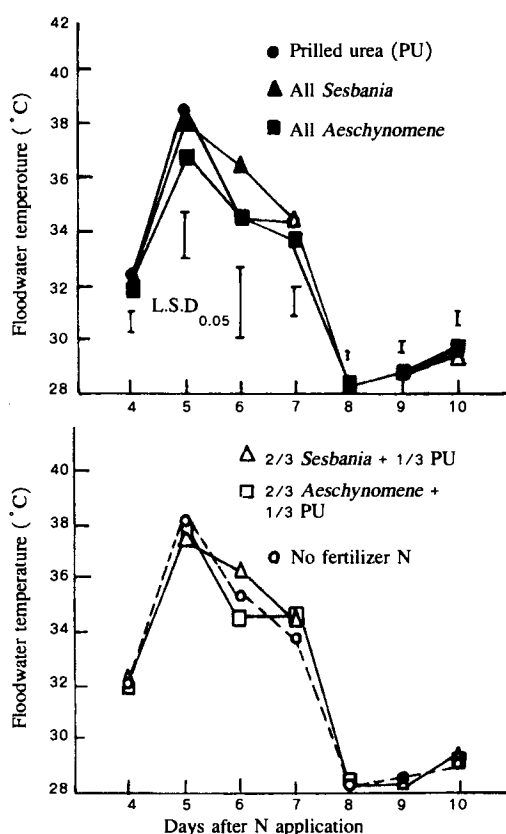


Figure 2. Floodwater temperature at 1300-1400 h as affected by green manure and urea amendment in broadcast seeded flooded IR72.

Floodwater pH when PU was applied alone was highest at 5 days after N application (Figure 3). Combined application of PU and green manure or applying green manure alone gave significantly lower floodwater pH presumably due to the CO_2 produced during green manure decomposition. Thus, N losses from PU applied alone are expected to be higher than that from combined application or from green manure applied alone. These results confirm that combined application of green manure and urea can reduce N losses from the inorganic N fertilizer application.

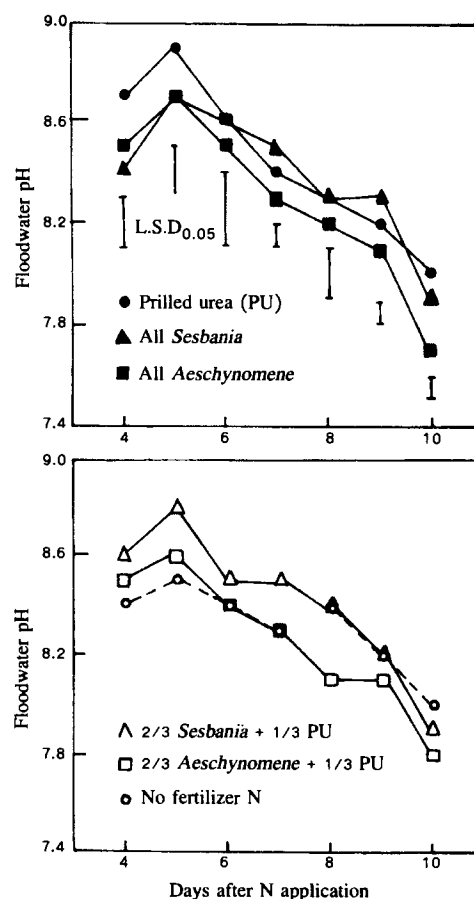


Figure 3. Floodwater pH at 1300-1400 h as affected by green manure and urea amendment in broadcast seeded flooded IR72.

Floodwater pH with BSFR and those with TPR IR72 were compared after PU was topdressed at 5-7 DBPI. In N fertilized treatments, floodwater pH was lower

with BSFR than that with TPR (Figure 4). The effect of algal photosynthesis was apparent during later crop growth stages. Mikkelsen *et al.* (1978), Craswell and Vlek (1979), and Muirhead *et al.* (1989) reported that the aquatic biota, which consumes CO_2 normally from the floodwater, mainly affects the diurnal pH changes in floodwater. Canopy light extinction, which is more pronounced in BSFR, lowered the photosynthetic activity of the aquatic biota, thus increased CO_2 concentration and reduced floodwater pH. However, PU broadcast at 5-7 DBPI gave a much lower floodwater pH than did basal B&I of fertilizer N (Figures 3 and 4).

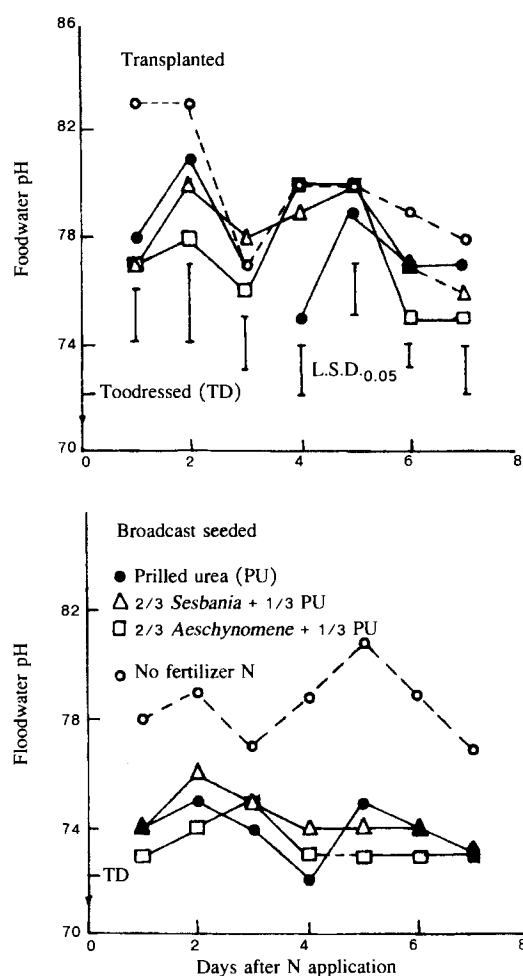


Figure 4. Floodwater pH at 1300-1400 h after topdressing as affected by green manure and urea amendment in transplanted and broadcast seeded flooded IR72.

Since partial pressure of ammonia (pNH_3) in the floodwater was used to gauge the potential NH_3 volatilization loss, pNH_3 in TPR and BSFR after N application was compared. During initial fertilizer application, when floodwater properties highly favored NH_3 volatilization loss, green manure applied alone or applied with PU generally gave significantly low pNH_3 than did PU applied alone. This was probably because decomposing green manure produced enough CO_2 and increased the partial pressure of CO_2 (pCO_2) in the floodwater. Since pCO_2 is inversely related to pH, reduced pH yields decreased pNH_3 . On the other hand, the opposing process of mineralization immobilization was prominent in combined application, which kept the floodwater NH_4^+ -N level low. Thus, combined application of green manure and PU can reduce NH_3 losses from floodwater. Topdressing of remaining 1/3 PU at 5-7 DBPI, however, resulted in lower pNH_3 than did B&I of PU during the initial fertilizer application (Figure 5). Similar observations have been reported by earlier works (Fillery *et al.*, 1984 ; De Datta *et al.*, 1987)

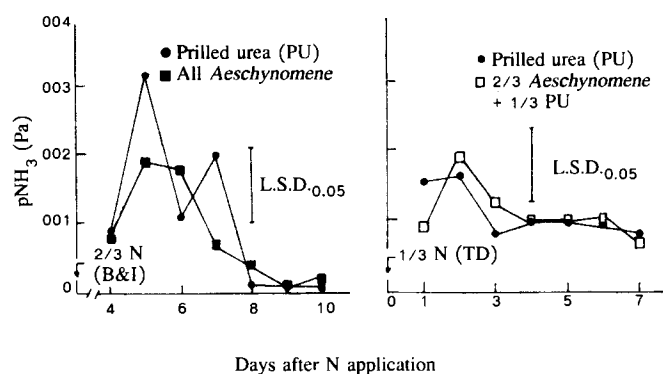


Figure 5. Partial pressure of NH_3 (pNH_3) in floodwater at 1300-1400 h as affected by *Aeschynomene afraspera* green manure and urea amendment in broadcast seeded flooded IR72. TD = topdressed, B & I = broadcast and incorporated.

Grain Yield , Straw Yield and Harvest Index (HI)

Incorporation of *Sesbania* and *Aeschynomene* green manures or PU-green manure combinations significantly increased rice grain yield in both TPR and BSFR compared with the no fertilizer N control (Table 3).

In TPR , although green manure increased vegetative growth and straw production , it did not give higher grain yield than did PU applied alone. Prilled urea applied alone gave lower HI because straw yield production was higher with PU applied alone than that with green manure treatments.

Table 3. Grain and straw yield, harvest index and agronomic efficiency of transplanted and broadcast seeded flooded IR72 as affected by green manure and urea amendment.[△]

N Source	Grain Yield (t/ha)	Straw Yield (t/ha)	Harvest Index	Agronomic Efficiency
Transplanted				
No fertilizer N	2.2	3.1	0.41	-
Prilled urea (PU)	3.4	5.0	0.40	20
All <i>Sesbania</i>	3.2	4.8	0.40	17
2/3 <i>Sesbania</i> +1/3 PU	3.5	4.6	0.43	22
All <i>Aeschynomene</i>	3.1	4.5	0.42	15
2/3 <i>Aeschynomene</i> +1/3 PU	3.3	4.9	0.40	18
Broadcast seeded				
No fertilizer N	2.2	3.5	0.39	-
Prilled urea (PU)	3.7	6.9	0.35	25
All <i>Sesbania</i> (PU)	3.3	5.6	0.37	18
2/3 <i>Sesbania</i> +1/3 PU	3.5	5.9	0.37	22
All <i>Aeschynomene</i>	3.0	5.4	0.36	13
2/3 <i>Aeschynomene</i> +1/3 PU	3.4	5.6	0.37	19
L.S.D (0.05)	0.3	0.7	0.02	
C.V. (%)	6	10	4	

[△]Av. of 4 replications.

In BSFR , *Sesbania* as N source generally gave higher grain yields than did *Aeschynomene* (Table 3). *Aeschynomene* was noted to have faster decomposition caused by lower C/N ratio and lignin content (Table 2). This caused faster depletion of available N in the soil due to higher plant uptake during vegetation stage. However, HI of both *Sesbania* and *Aeschynomene* treatments were not significantly different. Harvest index was highest with no fertilizer N treatment followed by green manure treatments (both green manure alone and PU-green manure combinations). Prilled urea applied alone gave the lowest HI.

Grain yield from green manure-PU combinations were similar to that with PU applied alone but were significantly higher than those of all *Sesbania* and all *Aeschynomene* treatments. This demonstrates that an organic N source alone may not sustain high rice yield, hence the need for an integrated use of organic and inorganic N sources. Both *Sesbania* and *Aeschynomene* green manure gave low C/N ratio because they underwent fast decomposition to provide initially sufficient amount of N for rice plants. But during later stages high plant N demand was not met. Results showed that trends in yield response decreased at higher green manure rates. Similar results have been reported earlier (Watanabe *et al.*, 1977; Westcott and Mikkelsen, 1987; Biswas, 1988).

Two-thirds of the recommended N dose as B&I green manure + 1/3 N as PU topdressed at 5-7 DBPI produced the same grain yield as did researchers' split of PU (2/3 PU B&I + 1/3 PU topdressed), regardless of planting method. After green manure incorporation, soil NH_4^+ -N concentration steadily increased to peak at the 3rd week (Figure.1) , then gradually declined at least 2 weeks later to level with that of the native soil NH_4^+ -N.

Results suggest that topdressing of inorganic N is needed at later crop growth stages to obtain high grain yield when organic green manure is B&I. Morris *et al.* (1986) and Nagarajah *et al.* (1989) reported similar

findings with single and split application of N with green manure.

Agronomic Efficiency

Broadcast seeded flooded rice gave similar agronomic efficiency to TPR based on similar grain yield of BSFR and TPR with added N. Mean grain yields of both planting methods were , however, the same (2.2 t/ha) with no N applied (Table 3). The higher agronomic efficiency in BSFR can be attributed to lower N losses through volatilization and immobilization as indicated by ^{15}N studies (De Datta *et al.*, 1988 ; Schnier *et al.*, 1988).

In BSFR, PU applied alone gave the highest agronomic efficiency (25kg rice/kg N) followed by PU-*Sesbania* combinations (22 kg rice/kg N) and PU-*Aeschynomene* combinations (19 kg rice/kg N). Basal incorporation of N as *Aeschynomene* ranked lowest with 13 kg rice/kg N applied (Table 3).

Results suggest that PU best split still gives consistently higher agronomic efficiency over PU-green manure combinations or green manure applied alone. Biswas (1988) obtained similar results in TPR, but Furoc and Morris (1989) found similar agronomic efficiency with PU and *Sesbania* application at low rates.

Yield components

Applying 2/3 *Aeschynomene* + 1/3 PU gave highest panicle number per square meter in both planting methods. Two-thirds of *Sesbania* + 1/3 PU gave highest spikelet number per panicle in TPR, whereas *Aeschynomene* applied alone gave highest spikelet number per panicle in BSFR. However, the different N sources did not affect percent unfilled spikelets and 100-grain weight (Table 4).

Panicle number per square meter of BSFR was generally higher than that of TPR , but spikelet number per panicle of BSFR was lower. Broadcast

seeded flooded rice's high panicle number, however, did not fully compensate for its low spikelet number per panicle, hence, total spikelet number per unit area was not higher than that in TPR. Grain yield was therefore similar in both planting methods.

Table 4. Yield component of transplanted and broadcast seeded flooded IR72 as affected by green manure and urea amendment.[△]

N Source	Panicle NO. (no./m ²)	Spikelet (no./panicle)	Unfilled Spikelets (%)	100-grain weight (g)
Transplanted				
No fertilizer N	224	91	40	2.37
Prilled urea (PU)	305	96	42	2.35
All <i>Sesbania</i>	280	101	38	2.36
2/3 <i>Sesbania</i> +1/3 PU	301	107	38	2.36
All <i>Aeschynomene</i>	297	96	39	2.35
2/3 <i>Aeschynomene</i> +1/3 PU	313	90	33	2.38
Broadcast seeded				
No Fertilizer N	318	66	43	2.34
Prilled urea (PU)	372	90	34	2.45
All <i>Sesbania</i>	364	75	40	2.42
2/3 <i>Sesbania</i> +1/3 PU	395	87	43	2.44
All <i>Aeschynomene</i>	404	82	39	2.28
2/3 <i>Aeschynomene</i> +1/3 PU	425	84	39	2.47
L.S.D (0.05)	77	21	ns	ns
C.V. (%)	16	16	13	3

[△]Av. of 4 replications. ns = not significant.

Leaf Area Index (LAI)

Fertilizer N added to the soil significantly influenced LAI throughout crop growth. Leaf area index significantly differed between nonfertilized control and fertilizer N added treatments in both planting methods. However, LAI did not significantly differ among fertilizer N added treatments (Figure 6).

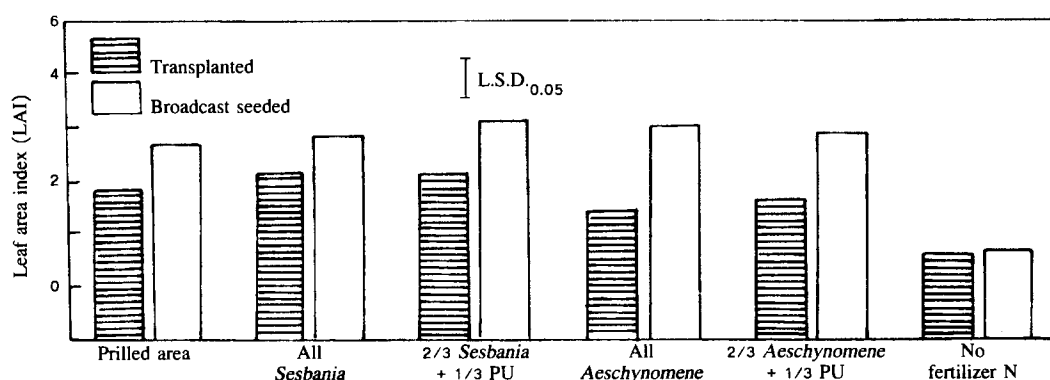


Figure 6. Leaf area index of transplanted and broadcast seeded flooded IR72 just before flowering stage as affected by green manure and urea amendment.

Leaf area index of BSFR was significantly higher than that of TPR because of higher plant density per unit land area of BSFR. Generally, it limited growth during the vegetative stage. During the reproductive stage, LAI was abundant and plant N concentration became limiting, particularly in BSFR. Thus, further growth and grain yield increase in BSFR depend on improved nutrient management practices. The negative effect, however, on grain yield of a high LAI during the reproductive stage has been demonstrated by Fagade and De Datta (1971). Thus, the desired plant type is characterized by lodging resistance, high N uptake, low tillering ability and limited leaf area during the reproductive growth stage.

Conclusion

The response of broadcast seeded flooded (BSFR) and of transplanted (TPR) IR72 to green manure amendment with and without prilled urea (PU) were compared. Two tropical, stem - nodulating

legumes *Sesbania* and *Aeschynomene* were green manure crops tested.

Compared with PU alone, combined application of green manure and PU substantially reduced N losses from NH_3 volatilization. It also gave significantly lower floodwater pH and partial pressure of ammonia (pNH_3) than did PU applied alone. The kinetics of exchangeable NH_4^+ -N were monitored after basal incorporation of fertilizer N. Both green manure underwent quick decomposition and mineralization and thus caused soil NH_4^+ -N to rapidly increase within the first 21 days after N application. Green manure -PU combinations gave grain yields similar to that with PU applied alone. Green manure applied alone gave significantly lower grain yields. This demonstrates that because organic N source applied alone may not sustain higher rice yield. The low C/N ratio in *Sesbania* and *Aeschynomene* may be attributed to the fact that both species underwent fast decomposition to provide initially sufficient amount of N for rice plant. During later crop growth stages, however, high plant N demand was not met. Between green manures, *Sesbania* as N source generally gave significantly higher grain yields than did *Aeschynomene*.

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