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EFFECTS OF UREA, *AZOLLA* AND *SESBANIA* INCORPORATION ON THE CONCENTRATION AND UPTAKE OF N, P, K AND S IN RICE *(ORYZA SATIVA)*

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A field experiment was conducted to examine the effect of urea, *Azolla,* and *Sesbania* incorporation on N, P, K and S concentration and uptake in BR11 rice. *Sesbania* plants (with or without *Bradyrhizobium* inoculation) were incorporated to soil after 70 days of sowing. *Azolla* was mixed with soil after 20 days of its application. The *Sesbania* treatment resulted in the highest nutrient concentration and uptake in rice. Next to *Sesbania* (inoculated), urea and *Sesbania* (uninoculated) played a good role in improving nutrient level of rice. *Azolla* manuring did not give good result due to poor growth because of high temperature prevailing during the growth period. Ratio of N-P, N-K and N-S concentrations in both grain and straw were fairly constant during the treatments.

Key words: *Azolla,* Micronutrient uptake, Rice, *Sesbania,* Urea.

Introduction

Nitrogen is the key element limiting crop production in Asia. Recently, stagnant or declining yields under continuous rice cropping and the possible adverse effects of using high levels of chemical N fertilizer on the environment (Cassman and Pingali 1995) have raised serious concern about the long-term sustainability of such a production system. Legumes, by virtue of their ability to fix N, have the potential to make substantial contribution to the N economy of lowland rice cropping systems in the tropics (Ladha and Kundu 1979). As stocks of non-renewable energy resources (fossil fuels) are depleting, the prices of N fertilizers are likely to increase steadily, making their use economically unattractive in the near future. Biologically N fixing (BNF) systems offer an economically attractive and environmentally safe means of reducing external inputs of chemical fertilizers and improving internal resources (Ladha and Peoples 1995).

Sesbania and *Azolla* can be potential sources of green manure for tropical rice production for their high N fixing capacity and the availability of this nitrogen to the standing rice crops. *Bradyrhizobium* bacteria live in association with *Sesbania* plants and gather molecular nitrogen from atmosphere (Rao 1988). *Azolla* is a free-floating aquatic fern which fixes atmospheric dinitrogen through symbiosis with a blue-green alga, *Anabaena azollae* (Mian 1993). The usefulness of *Azolla* for increasing rice yield has been reported in various countries (Kumarasinghe and Eskew 1993; Malik *et al* 1998). The present study was undertaken to evaluate the comparative performance of *Sesbania, Azolla* and urea on N, P, K and S content in rice.

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Materials and Methods

The experiment was conducted in the Old Brahmaputra Floodplain soil at Bangladesh Agriculture University Farm, Mymensingh. The soil was silt loam having 6.4 pH, 1.85% organic matter, 0.125% total N, 12.0 $\mu g\ g^{-1}$ available P, 0.3 meq $100g^{-1}$ exchangeable K and 20 $\mu g\ g^{-1}$ available S. The experiment was laid out in a randomized complete block design with four replications. The treatments were then randomly distributed to the plots, each measuring 5m x 4m. Basal application was made with triple superphosphate, muriate of potash and gypsum to supply 60 kg P_2O_5 ha^{-1}, 40 kg K_2O ha^{-1} and 20 kg S ha^{-1}, respectively. The crop variety was BR11 (Mukta) rice. Rice seedlings were transplanted after four weeks of *Sesbania* incorporation. The five treatments were as follows:

i) *Control.* No urea, *Sesbania* or *Azolla* was applied.

ii) *Urea application.* Urea was applied at the rate of 80 kg N ha^{-1} in three equal splits during land preparation and after 30 and 60 days of transplanting.

iii) *Azolla manuring.* Fresh *Azolla (A. pinnata)* was applied at the rate of 0.33 kg m^{-2} after seven days of transplanting of rice seedlings. *Azolla* did not form a thick mat because of high temperature (30±2°C) when it was incorporated to soil after 20 days of application. Azolla biomass was not weighed before incorporation.

iv) *Sesbania (uninoculated) manuring: Sesbania* seeds were sown without *Bradyrhizobium* inoculation. The plants were chopped and ploughed down after 70 days of growth. Before incorporation, biomass weight was recorded from $1m^2$ $plot^{-1}$, the yield being 3.88 t ha^{-1} and the nodule no. $plant^{-1}$ being 8.7.

v) *Sesbania (inoculation) manuring:* Seeds of *Sesbania aculeta* were coated with peat based *Bradyrhizobium* inoculant at the rate of 100 g kg^{-1} seed using gum acacia as the sticking agent. *Sesbania* seeds were sown in the respective plots and were allowed to grow up to 70 days. Thereafter, the plants were chopped and ploughed down in the soil. Before incorporation, nodule no. $plant^{-1}$ and biomass yield were recorded as 11.2 and 4.56 t ha^{-1}, respectively. Intercultural operations viz. weeding, irrigation and insecticide spray were done whenever required.

The crop was harvested at maturity after four months of transplanting. Grain and straw samples from every plot were analyzed for N, P, K and S concentrations. The uptake results were calculated from the yield and nutrient concentration data. The samples were digested with HNO_3-$HClO_4$ mixture (5:1) for P, K and S determination. The elemental concentrations in the digest were determined following the method as outlined by Page *et al* (1982). *Sesbania* (uninoculated and inoculated) plants were analysed for N, P, K and S contents. Uninoculated *Sesbania* contained 1.55% N, 0.137% P, 1.26% K and 0.207% S and inoculated *Sesbania* had 1.84% N, 0.161% P, 1.03% K and 0.262% S. The data obtained with different treatments were statistically analysed by F-test and the mean comparisons were made by LSD test.

Results and Discussion

N concentration and uptake. The N concentration in grain or straw was significanty influenced by the treatments. Nitrogen concentration in grain ranged from 0.92 to 1.16% while in straw from 0.58 to 1.03% (Table 1). Both grain and straw N concentrations were highest in *Sesbania* (inoc.) treatment and lowest in control. Statistically grain N concentrations due to urea, *Sesbania (inoc.)* and *Sesbania* (uninoc.) treatments were identical. Similarly, the N concentration in grain did not differ significantly between *Azolla* and control treatments. Similar results were noted with straw N concentration except that *Sesbania* (inoc.) manuring recorded significantly higher N concentration than any other treatment. A similar trend of N uptake by grain and straw due to various treatments was noted, and the highest N uptake by both grain and straw was recorded for *Sesbania* (inoc.) treatment and the lowest for the control. Nitrogen uptake due to *Sesbania* (inoc.) manuring was significantly higher than N uptake recorded for other treatments. Further, the level of N uptake by grain or straw as noted in *Sesbania* (uninoc.) and urea was significantly higher than that in *Azolla* or control treatment. The highest N uptake by grain and straw together was 96.3 kg ha^{-1} due to *Sesbania* (inoc.)which was followed by 80.9 kg ha^{-1} due to urea, 75.4 kg ha^{-1} due to *Sesbania* (uninoc.), 56.0 kg ha^{-1} due to *Azolla* and 46.1 kg ha^{-1} due to control.

P concentration and uptake. Like N concentration, P concentration in grain and straw was significantly affected by the treatments. *Sesbania* (inoc.) recorded the highest P content in grain and straw, and control treatment did the lowest (Table 2). The highest P concentration obtained with *Sesbania* (inoc.) application was significantly higher than that observed in any other treatment. Indeed, grain-P concentration due to each treatment was significantly different and it followed the order: *Sesbania* (inoc.) > *Sesbania* (unionc.) > urea > *Azolla* > control. Similar trend was found with straw-P concentration except that *Sesbania* (unionc.) was statistically similar to urea and they got the second position. It appears from Tables 2 that grain P concentration was nearly double than straw P concentration showing a range of 0.415-0.550% P in grain and 0.207-0.273% P in straw. The highest P uptake by grain or straw was observed in *Sesbania* (inoc.) and the lowest in control as was noted with N uptake by grain and straw. Grain P uptake due to *Sesbania* (uninoc.) and urea treatments was statistically similar but was significantly higher than that noted with *Azolla* or control. In recording straw-P uptake, *Sesbania*

Table 1

Effects of urea, *Azolla* and *Sesbania* incorporation on N content in rice

Treatment	N concentration %		N uptake (kg ha^{-1})		Total N uptake (kg ha^{-1})
	Grain	Straw	Grain	Straw	
Control	0.92	0.58	28.0	18.1	46.1
Urea	1.08	0.84	43.3	37.6	80.9
Azolla	1.00	0.63	34.6	21.4	56.0
Sesbania (uninoc.)	1.07	0.75	42.4	33.0	75.4
Sesbania (inoc.)	1.16	1.03	50.5	45.9	96.3
$LSD_{0.05}$	0.14	0.13	6.7	7.9	14.6

Results are the average of four replicates.
uninoc., uninoculated; inoc. , inoculated with *Bradyrhizobium* inoculant.

(inoc.) did not differ significantly from *Sesbania* (uninoc.) or urea treatment. When grain-P and straw-P uptakes were combined, the highest result of 36.2 kg ha^{-1} was recorded with *Sesbania* (inoc.) manuring which was followed by 32.3 kg ha^{-1} due to *Sesbania* (unionc.), 31.9 kg ha^{-1} due to urea and 32.2 kg ha^{-1} due to *Azolla* incorporation.

K concentration and uptake. Potassium concentration in grain showed a similar trend as observed with P concentration in grain. Thus, grain-K concentration due to various treatments followed the order: *Sesbania* (inoc.) > *Sesbania* (uninoc.) > urea > *Azolla* > control while unlike grain-P concentration, *Sesbania* (uninoc.) treatment showed the highest straw-K concentration and *Sesbania* (inoc.) ranked second. In contrst to P results, straw-K concentration was about 5-6 times higher than grain-K concentration. Grain-K concentration was found to vary from 0.193 to 0.235% and straw-K from 1.00 to 1.38%. Similar to K concentration, the highest K uptake was observed with *Sesbania* (inoc.) treatment in case of grain and with *Sesbania* (unionc.) for straw. Total K uptake by grain and straw in *Sesbania* (inoc.) was 70.6 kg ha^{-1} 70.1 kg ha^{-1} in *Sesbania* (uninoc.), 69.2 kg ha^{-1} in urea and 51.3 kg ha^{-1} in *Azolla.*

S concentration and uptake. Like N, P and K concentrations in grain and straw, S concentration was also significantly affected by the treatments (Table 4). The highest grain and straw S concentration obtained with *Sesbania* (inoc.) treatment was statistically similar to that observed in urea or *Sesbania* (unionc.) treatment. Grain-S concentration ranged from 0.098 to 0.117% and straw-S from 0.088 to 0.106%. Like N and P uptake, S uptake by grain and straw was highest in *Sesbania* (inoc.) treatment and the lowest in control. The highest S uptake of 5.13 kg ha^{-1} by grain was recorded due to *Sesbania* (inoc.) manuring which was significantly higher than the rest of the treatments. In case of straw-S uptake, *Sesbania* (inoc.), *Sesbania* (uninoc.) and urea treatments were statistically identical and were significantly different from others. The total S uptake as recorded by *Sesbania* (inoc.) was 9.89 kg ha^{-1}.

Nutrient ratios in grain and straw. An attempt has been made to examine the ratios of N-P, N-K and N-S concentra-

Table 2

Effects of urea, *Azolla* and *Sesbania* incorporation on P content in rice

Treatment	P concentration %		P uptake (kg ha^{-1})		Total P uptake (kg ha^{-1})
	Grain	Straw	Grain	Straw	
Control	0.415	0.207	12.6	6.5	19.1
Urea	0.510	0.255	20.5	11.4	31.9
Azolla	0.447	0.228	15.5	7.7	23.2
Sesbania (uninoc.)	0.527	0.255	21.0	11.3	32.3
Sesbania (inoc.)	0.550	0.273	24.0	12.2	36.2
$LSD_{0.05}$	0.002	0.014	2.3	2.3	4.6

Results are the average of four replicates.
uninoc. = uninoculated; inoc = inoculated with *Bradyrhizobium* inoculant.

Table3

Effects of urea, *Azolla* and *Sesbania* incorporation on K content in rice

Treatment	K concentration %		K uptake (kg ha^{-1})		Total K uptake (kg ha^{-1})
	Grain	Straw	Grain	Straw	
Control	0.193	1.00	5.9	31.2	37.1
Urea	0.225	1.34	9.0	60.2	69.2
Azolla	0.210	1.30	7.3	44.0	51.3
Sesbania (uninoc.)	0.228	1.38	9.1	61.0	70.1
Sesbania (inoc.)	0.235	1.34	10.3	60.3	70.6
$LSD_{0.05}$	0.002	0.02	1.2	12.0	13.2

Results are the average of four replicates.
uninoc. = uninoculated; inoc = inoculated with *Bradyrhizobium* inoculant.

Table 4
Effects of urea, *Azolla* and *Sesbania* incorporation on S content in rice

Treatment	S concentration %		S uptake (kg ha^{-1})		Total S uptake (kg ha^{-1})
	Grain	Straw	Grain	Straw	
Control	0.098	0.088	2.97	2.72	5.69
Urea	0.113	0.101	4.52	4.52	9.04
Azolla	0.106	0.095	3.68	3.22	6.90
Sesbania (uninoc.)	0.113	0.099	4.49	4.40	8.89
Sesbania (inoc.)	0.117	0.106	5.13	4.76	9.89
$LSD_{0.05}$	0.001	0.010	0.56	0.91	1.47

Results are the average of four replicates.
uninoc. = uninoculated; inoc = inoculated with *Bradyrhizobium* inoculant.

Table5
Nutrient ratios in grain and straw of rice as affected by different treatments

Treatment	N:P		N:K		N:S	
	Grain	Straw	Grain	Straw	Grain	Straw
Control	2.2	2.8	4.8	0.58	9.4	6.6
Urea	2.1	3.7	4.8	0.63	9.6	8.3
Azolla	2.2	2.7	4.8	0.48	9.4	6.6
Sesbania (uninoc.)	2.0	3.3	4.7	0.54	9.5	7.5
Sesbania (inoc.)	2.1	3.7	4.9	0.76	9.9	9.7

Results are the average of four replicates.
uninoc. = uninoculated; inoc = inoculated with *Bradyrhizobium* inoculant.

tions in grain and straw as affected by the treatments. It appears from Table 5 that the ratios of N to P, K or S were fairly constant during the treatments. The data (Table 5) show that the N-P ratio in grain was concentrated to 2.2±0.1, the N-K ratio 4.8±0.1 and N-S ratio being 9.6±0.2. In contrast to the nutrient ratios in grain, the straw ratios slightly varied from treatment to treatment. In straw, the N-P ratio ranged from 2.8 to 3.7 with an average of 3.2, the N-K ratio from 0.48 to 0.76 with an average of 0.60 and the N-S ratio from 6.6 to 9.7 having an average of 7.7. Such results support the idea that it is the tendency of a plant to maintain a constant nutrient ratio in its tissues. The constant N-S ratio otherwise indicates the formation of S-containing amino acid (e.g.cystine,cysteine and methionine)in grain. Any element that is essential for the growth and development of plants must have a direct or indirect influence on N-metabolism, including synthesis of protein.

Sesbania (inoc.) manuring gave the best results in the present study. Urea supplied only nitrogen to soil while *Sesbania* or *Azolla* provided nitrogen plus many other nutrients. Inoculated *Sesbania* exhibited better performance primarily because of higher nodulation, biomass and nutrient content compared to uninoculated *Sesbania*. *Azolla* did not give satisfactory results presumbably due to their unsatisfactory growth at higher temperatures (30±2°C) in August - September. Solaiman *et al* (1990) obtained good effect of *Azolla* in Boro rice where *Azolla* was grown and incorporated in the soil in January - February when temperature was 20±5°C. Lumpkin and Plucknett (1982) reported that the most favourable temperature for *Azolla* growth was around 25°C.

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