

AZOLLA AS A PARTIAL SUBSTITUTE FOR CHEMICAL NITROGEN FERTILIZER IN RICE

MALKANTHI K. GUNATILAKA*, NIRMALA GUNAPALA,
G. K. UPAWANSA*** and H. M. WIJERATHNABANDA******

ABSTRACT

Two field experiments were conducted at Gannoruwa for two consecutive seasons to evaluate the potential of *Azolla* as a nitrogen source for rice. The effects of *Azolla* on vegetative growth and grain yield of rice indicate that the addition of *Azolla* to the field about 15 days before transplanting was more effective than the addition of same after transplanting. *Azolla* added before transplanting at the rate of 3 tons (fresh weight) per ha gave a grain yield that is not significantly different to the grain yield obtained with the addition of 60 kg per ha in the form of urea.

INTRODUCTION

The urgent need for conservation of energy has created a world wide interest in biological nitrogen fixation. Intelligent manipulation of the various nitrogen fixing systems can contribute to cheaper ways of food production with lesser environmental and social constraints.

The current energy crisis has escalated the prices of nitrogenous as well as other fertilizers. Yet, in the area of chemical fixation no major breakthrough is visible to minimise the energy requirement of the conventional Harber-Bosch process for the production of ammonia.

The high production and transportation costs and their increased selling price has made it difficult for an average farmer in a developing country like Sri Lanka to buy commercial fertilizers in adequate quantities. To circumvent the problem of expensive fertilizers it is essential to seek cheaper ways of fertilizing paddy fields.

* Division of Botany, CARI, Gannoruwa, Peradeniya.

** Division of Chemistry, CARI, Gannoruwa, Peradeniya.

*** School of Agriculture, Angunukolapelessa.

**** In-Service Training Institute, Gannoruwa, Peradeniya.

Azolla-Anabaena complex is a symbiotic association between a floating aquatic fern *Azolla* and a nitrogen fixing blue-green alga *Anabaena azollae* occurring as an endophyte in special cavities on the ventral surface of the dorsal lobe of the fern leaf (Moore, 1959; Ashton and Walmsley, 1976; Becking, 1976; & Watanabe, 1978).

When grown in flooded rice fields this fern-algal complex can fix atmospheric nitrogen and supply it to the rice crop after decomposition of the fern (Watanabe *et al*, 1977; Watanabe, 1978; Lumpkin and plucknett 1982).

This study was undertaken to find the effects of *Azolla* inoculation on vegetative growth and yield of rice.

MATERIALS AND METHODS

Field experiments using new-improved, high-yielding, high fertilizer responsive rice variety Bg 94-1 ($3\frac{1}{2}$ months) were conducted in a randomized complete block design with four replications for two consecutive seasons, Yala 1980 and Maha 1980/81 at Gannoruwa in the Mid-Country Wet Zone of Sri Lanka. The treatments employed are shown in Table 1. Some physical and chemical properties of the soil at this location are shown in Table 2.

Rice seedlings at the age of 18 days were transplanted in field plots of size 3m×3m separated by 30 cm wide ridges. Transplanting was done in rows at a spacing of 20 cm between rows and 15 cm within rows with 3 seedlings per hill.

Urea, concentrated super phosphate and muriate of potash were used as sources of N, P and K respectively. Phosphorus at the rate of 110 kg P_2O_5 /ha and potassium at the rate of 55 kg K_2O /ha were added in eight equal splits at weekly intervals. The first split application of P and K fertilizers in treatments 4 and 6 was done 15 days before transplanting with the inoculation of *Azolla*. In all other plots the first split application of P and K fertilizers was done just before transplanting.

Nitrogen fertilizer was applied in four splits in the ratio of $\frac{1}{4}, \frac{1}{4}, \frac{1}{4}, \frac{1}{4}$, at transplanting, two weeks after transplanting, four weeks after transplanting and seven weeks after transplanting.

AZOLLA AS PARTIAL SUBSTITUTE FOR CHEMICAL NITROGEN

In treatments 4, 5 and 6 the inoculation of *Azolla* at the rate of 3 tons (fresh weight) per ha was done only once. In about a week after inoculation *Azolla* covered the total surface area of the plots. Incorporation of *Azolla* into the soil was done five times at ten day intervals.

Incorporation was done manually after draining off the standing water in the plots. Approximately 50% of the *Azolla* mass in each plot could be incorporated into the soil by this method.

The normal cultivation practices for rice were followed throughout the duration of the experiment. In addition, the Lepidopterous caterpillars that destroy *Azolla* were controlled by treating the plots with carbofuran (3 kg a.i./ha).

Plant growth records, namely plant height and tiller number were taken at four weeks after transplanting, at six weeks after transplanting and at maturity from 12 pre-determined hills from each plot.

At maturity, harvesting was carried out after removing two border rows of plants from each plot. Grain yield was recorded at 14% moisture (Table 3).

RESULTS AND DISCUSSION

Figure 1 shows the plant height taken at four weeks after transplanting, at six weeks after transplanting and at maturity. Figure 2 shows the tiller numbers taken at four weeks after transplanting, at six weeks after transplanting and the productive tiller number taken at harvest.

Inoculation of *Azolla* before transplanting of rice has caused a better plant growth than when inoculation of the same quantity of *Azolla* was done at transplanting (Figures 1 & 2). When the inoculum was given two weeks before transplanting, at the given rate, it produced a complete cover in about eight days before transplanting. During the various field operations prior to transplanting rice, the *Azolla* biomass gets incorporated into the soil, which facilitates quick and efficient decomposition and release of its nutrients. In fact, it has been shown that about 50% of the total nitrogen in *Azolla* is released as ammonia three weeks after its incorporation into the soil. About 75% of the total nitrogen becomes available by six weeks after incorporation (Watanabe, 1977). When the young rice seedlings are ready to

absorb the required nutrients from the soil, the nitrogen content of *Azolla* would be in a readily available form to the rice crop. Hence, the superior growth performance of rice when *Azolla* is added prior to transplanting.

Statistical analysis of the grain yield data for two consecutive seasons, Yala 1980 and Maha 1980/81 (Table 3), shows that the grain yield of rice obtained with an addition of *Azolla* at the rate of 3 tons (fresh weight) per ha before transplanting is not significantly different to the grain yield obtained with an application of 60 kg N per ha in the form of urea.

Further, the estimated linear regressions between the amount of nitrogen fertilizer applied in the form of urea and the grain yield show that the grain yield obtained with the addition of *Azolla* at the rate of 3 tons (fresh weight) per ha before transplanting is equivalent to an application of 50 to 57 kg N per ha in the form of urea (Figure 3 & 4).

Although there is no significant difference in grain yield data between treatment numbers 3 & 6, treatment number 6 has given a higher yield. Comparison of these two treatments would tempt one to speculate that addition of 3 tons (fresh weight) of *Azolla* per ha before transplanting would have the beneficial effect equivalent to addition of 30 kg N/ha in the form of urea. However, studies have shown rice yields comparable to 55—100 kg N/ha of chemical nitrogenous fertilizer with the use of *Azolla* (Watanabe *et al* 1981 and Kulasoorya *et al* 1984).

A combined analysis of the data over the two seasons tested indicates that the seasonal variations have no significant effect on the grain yield.

In treatment numbers 4, 5 & 6 where *Azolla* was utilized the initial inoculum rate was the same. However, there would have been a difference in the rates of growth of *Azolla* where it grew initially as a monoculture (Treatments 4 and 6) as opposed to the treatment where *Azolla* was not allowed to grow in monoculture (Treatment 5). Hence, there would have been a variation in the total biomass of *Azolla* incorporated into the soil. Since a quantitative estimation of the incorporated *Azolla* biomass was not performed in this study it is not possible to evaluate whether this variation would have had a significant reflection on the growth and yield of the rice crop.

AZOLLA AS PARTIAL SUBSTITUTE FOR CHEMICAL NITROGEN

In a similar investigation in progress, periodic incorporation of *Azolla* has been omitted and the level of phosphorus fertilizer used was reduced to about 60 kg P_2O_5 /ha, with an intention of minimising labour costs and making it a more acceptable technology for the average rice farmer.

In addition to this improvement in grain yield, there are other advantages of using *Azolla* for paddy cultivation eg. enrichment of soil with respect to organic matter content and suppression of weed growth. (Kulasooriya *et al* 1982).

Although the nitrogen content of *Azolla* is 3—5% on a dry weight basis (Watanabe *et al* 1977), comparable to that of other green manure crops, it has a considerably high potential as a substitute for synthetic nitrogen fertilizer, since the release of nitrogen is slow and persistent due to the continuous multiplication and degradation of the fern.

However, several practical difficulties in adopting this technology as an island wide recommendation will have to be mentioned, such as non availability of *Azolla* in the near vicinity, difficulty in culturing, localized problems of irrigation, bunding and difficulty in transporting *Azolla* from place to place since this fern undergoes autolysis when heaped up. In this context research on sporulation, storage and transportation of spores would be of importance in promoting this technology.

Further research in this field is necessary before it could be promoted extensively. Yet, in the light of existing research findings, the future of *Azolla* as a source of nitrogen in paddy cultivation is promising.

Once the above stated amendments have been investigated and a complete cost income evaluation computed, promoting this technology should not pose many practical problems.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support given by Dr. S. L. Amarasiri and Dr. A. S. Vivekanandan in the preparation of this manuscript by making useful comments and suggestions. Our thanks are also due to Mr. A. Gunasekara for his assistance in statistical analysis of data.

REFERENCES

- Ashton, P. J., and R. D. Walmsley (1976). The aquatic fern *Azolla* and its *Anabaena* symbiont. *Endeavor*, 35: 39—43.
- Becking, J. H. (1976). Nitrogen fixation in some natural ecosystems in Indonesia. *In* Proceedings of the First International Symposium on N-Fixation. Vol. 2. W. E. Newton and C. J. Nyman (eds.). Washington State University Press. p. 539—549.
- Kulasooriya, S. A., W. K. Hirimburegama and S. W. Abeysekara (1984). *Azolla* as a bio-fertilizer for rice in Sri Lanka. *In* Practical Application of *Azolla* for rice production. W. S. Silver and E. C. Schroder (eds). Martinus Nijhoff / Dr. W. Junk Publishers, Dordrecht / Boston / Lancaster. p. 188—207.
- Lumpkin, T. A. and D. L. Plucknett (1982). *In Azolla* as a Green Manure: Use and Management in crop production. Westview Tropical Agriculture Series No. 5 p. 109—140.
- Moore, A. W. (1959). *Azolla*: Biology and Agronomic Significance. *Bot. Rev.* 35: 17—34.
- Watanabe, I., C. R. Espinas, N. S. Perja and V. S. Alimagno (1977). Utilization of *Azolla-Anabaena* complex as a nitrogen fertilizer for rice. *IRRI Res. Paper Series*, No. 11.
- Watanabe, I. (1978). *Azolla* and its use in lowland rice culture. *Tsuchi To Biseibutsu* (Soil and Microbe, Japan) 20: 1—20.
- Watanabe, I., B. Ke-zhi, N. S. Herja, C. R. Espinas, O. Ito and B. P. R. Subudhi (1981). The *Azolla-Anabaena* complex and its use in rice culture. *IRRI Res. Paper Series*, No. 69.

AZOLLA AS PARTIAL SUBSTITUTE FOR CHEMICAL NITROGEN

Table 1 - List of treatments

1. Control
2. 30 kg N/ha in the form of urea
3. 60 kg N/ha in the form of urea
4. 3 tons *Azolla* (fresh weight) /ha before transplanting
5. 3 tons *Azolla* (fresh weight) /ha at transplanting
6. 3 tons *Azolla* (fresh weight) /ha before transplanting
+ 30 kg N/ha in the form of urea

Table 2 - Soil characteristics

Texture	Sandy clay loam
pH	5.2 — 5.4
Cation exchange capacity	15.2 meq per 100 g
Organic matter	3.2 %
Total nitrogen	0.2 %
Available phosphorus	28 kg P ₂ O ₅ / ha
Exchangeable potassium	0.1 meq per 100 g

Table 3 - Response of rice to addition of *Azolla*

Treatment	Yala 1980	Maha 1980 / 1981 ton / ha	Mean
1. Control	3.15	3.03	3.09
2. 30 kg N / ha	4.07	3.55	3.81
3. 60 kg N / ha	5.12	5.02	5.07
4. <i>Azolla</i> before transplanting	4.83	4.77	4.80
5. <i>Azolla</i> at transplanting	3.64	3.43	3.54
6. <i>Azolla</i> before transplanting + 30 kg N / ha	5.69	5.53	5.61
C. V.	15.43 %	10.30 %	
L. S. D. _{0.05}	1.25	0.66 ton / ha	
L. S. D. _{0.01}	1.72	0.91 ton / ha	

Figure 1. Plant Height

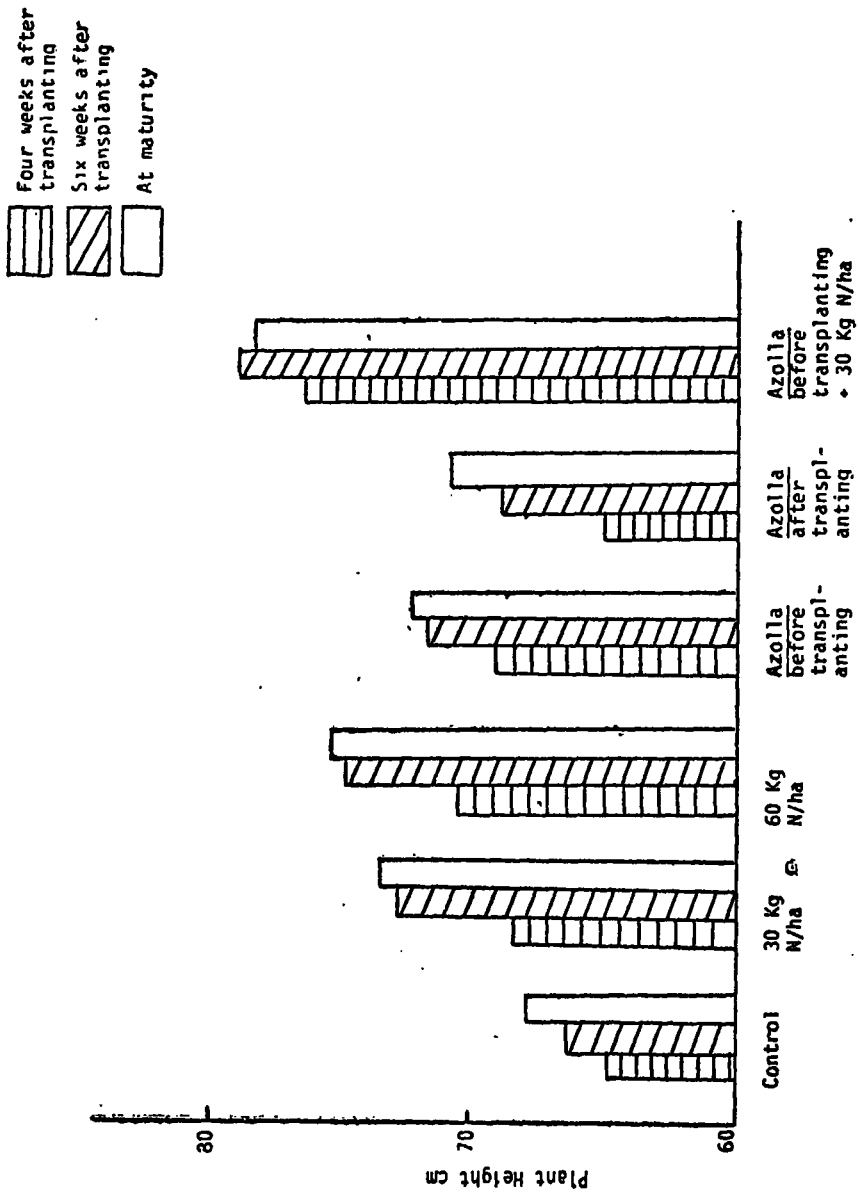


Figure 2. Number of Tillers per Hill

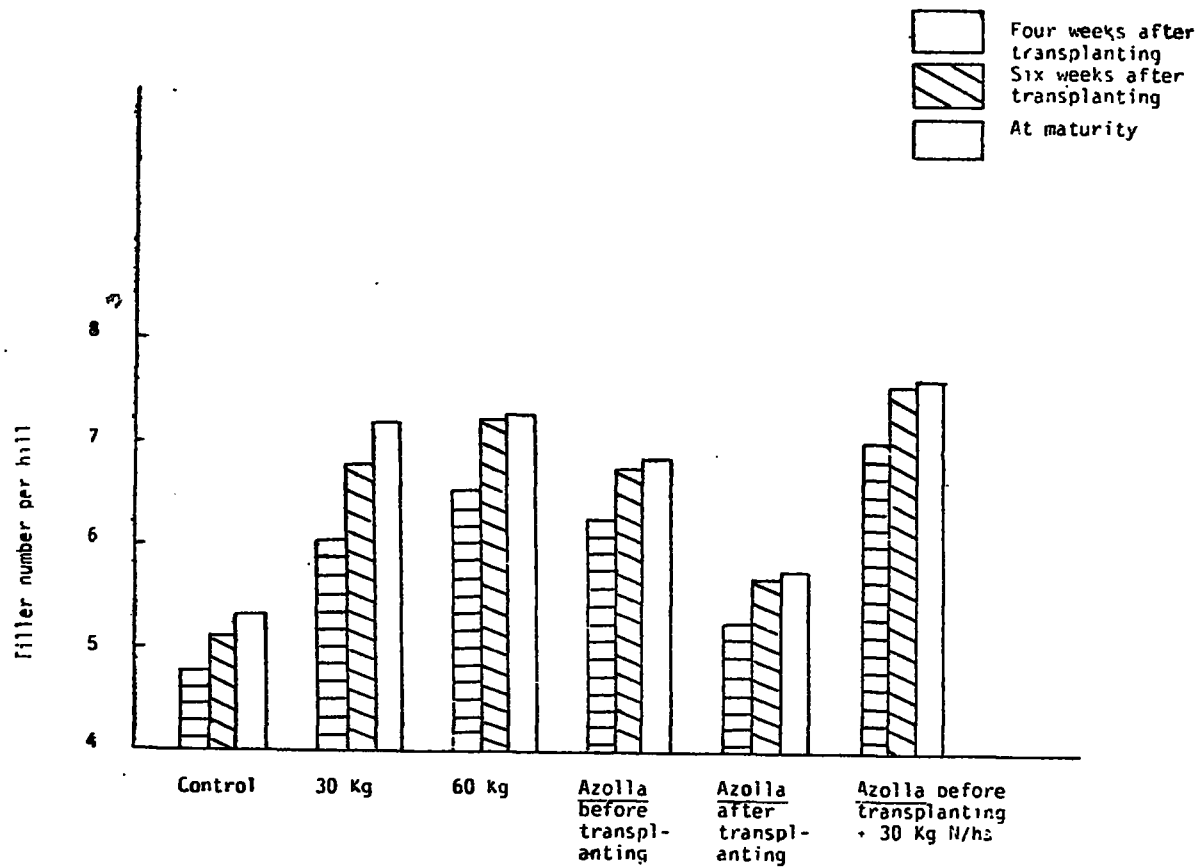


Figure 3. The estimated linear regression for grain yield data at three different levels of urea application - Yala 1980

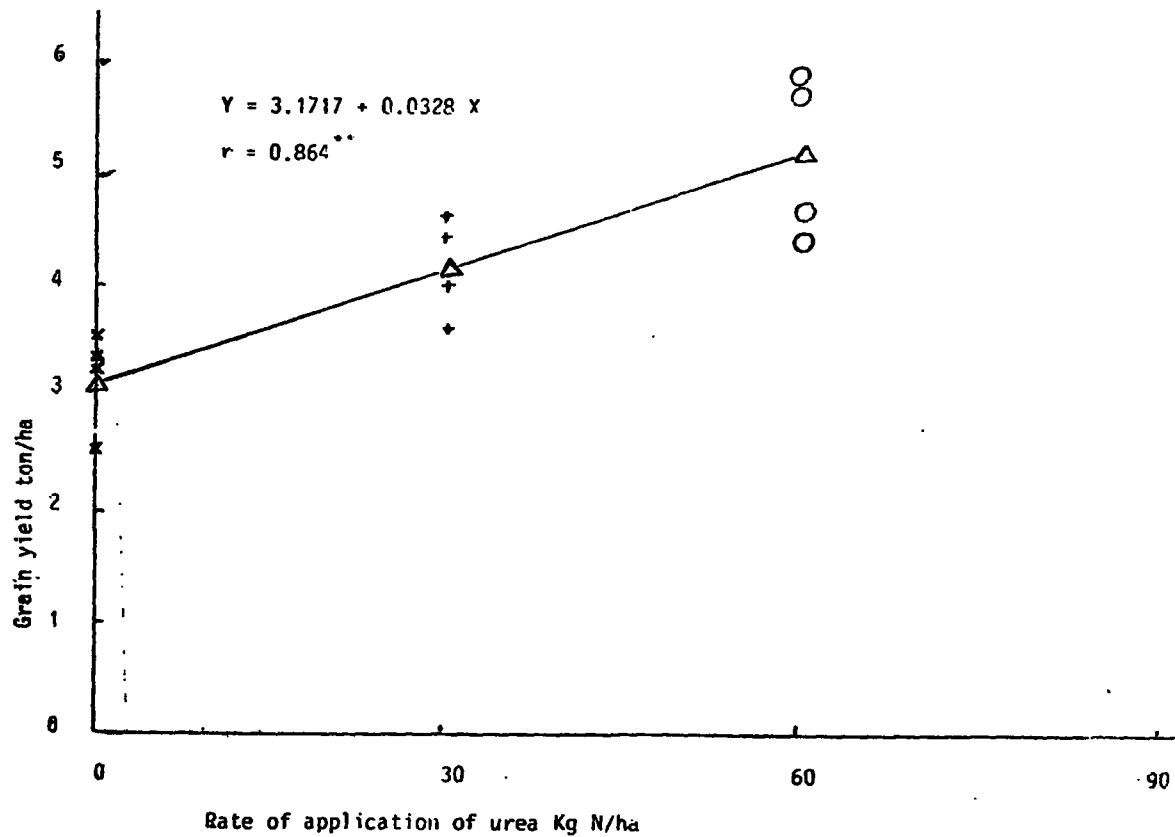


Figure 4. The estimated linear regression for grain yield data at three different levels of urea application – Maha 1980 / 81

