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Growth and Nitrogen Production Rates of *Azolla* (*Azolla microphylla*) as Affected by Its Cultivation Methods : An Economic Perspective in Rice Cultivation in Thailand

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ABSTRACT

A statistically designed experiment of randomized complete block (RCBD) with four treatments was conducted during the year 1995/96 in acid sulphate soil of the central plain of Thailand to evaluate the effects of methods of *Azolla* cultivation on its growth rate, N production rate and rice production. The results showed that *Azolla* growth rate was not affected by cultivation methods used. But, N production and its production rate were significantly differed between the cultivation methods used. *Azolla* grown as a monocrop 20 days before transplanting was found superior in N production rate compared to that of N rate produced by dual cropped *Azolla*. The grain yield production per kg *Azolla*-N applied resulted in higher rate of grain production as compared with monocroped *Azolla* in addition to urea-N on rice when *Azolla* - N alone was applied to rice. The grain production per kg *Azolla*-N was found higher when *Azolla* was applied along with urea-N to rice grown as a dual crop compared to that of *Azolla* grown as a monocrop and incorporated at transplanting along with the urea-N application to rice. The effeciency of urea-N in grain production was increased when *Azolla* and urea-N were applied together to the rice crop. The *Azolla* grown as a dual crop with rice produced economically higher yields compared to that of other cultivation practices used.

Key words : N - production rate, *Azolla microphylla,* cultivation methods, monocrop, net return.

INTRODUCTION

Shortage of nitrogen is often the major factor which limits rice productivity. In many instances, this limitation can be off - set through the use of *Azolla* in rice cultivation. The use of *Azolla* and its N_2 - fixing associated with wetland rice field have been major focuses in recent years to researchers (Watanabe *et al.,* 1977).

Azolla, an aquatic fern, is used in the People's Republic of China and Vietnam as a green manure in flooded rice cultivation. The *Azolla* plants host and the blue-green algae *Anabaena azollae* live symbiotically and fix atmospheric dinitrogen (N_2)

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(Lumpkin and Plucknett, 1982). Under suitable field conditions *Azolla* becomes double in weight every 3 - 5 days and fixes atmospheric N_2 at a rate exceeding that of the legume/rhizobium symbiosis. *Azolla* can accumulate 2 - 4 or more kilograms of nitrogen /ha/day or equivalent to 10 - 20 kg of ammonium sulphate (Lumpkin and Plucknett, 1982). In this regard, it can play an important role in nutrition of rice plants with *Azolla*–N. The growth rate, minimum biomass, and N_2-fixing activity in optimum conditions provide the estimates of the potentials of *Azolla* - *Anabaena* symbiosis for agriculture. Talley *et al.* (1977) summerized the experimental results on the growth rates of *Azolla* and reported that the doubling time of *Azolla* was found as long as 7 days. The growth rate and N_2-fixing rate of *Azolla* greatly determine its production potentials to rice crop. The *Azolla* cultivation methods and phosphorus application play an important role on its production rates. This study mainly aims to attain the following objectives:

1. To study the effects of *Azolla* cultivation methods on its growth and N - production.
2. To study the economical importance of *Azolla* used in rice cultivation.

MATERIALS AND METHODS

A statistically designed experiment of randomized complete block (RCBD) with 4 treatments and 4 replications was conducted during the year 1995/96 in Pathumthani Rice Research Center. The soil was acid sulphate and was classified as Sulfic Tropaquepts, Rangsit soil series. The study was carried out to evaluate the effects of treatments (Table 1) on *Azolla microphylla* grown as a monocrop before transplanting of rice (*Oryza sativa* L. cv.RD 23) (A1) or as a dual crop with rice (A2). Three practices of rice cultivattion methods with *Azolla* were employed: 1. *Azolla* grown 20 days before transplanting, incorporated before transplanting and urea - N was not applied to rice (A1N0P); 2. *Azolla* was grown 20 days before transplanting, incroporated at transplanting and urea-N was given to rice at transplanting and at panicle initiation stage (PI) (A1N1P); and 3. *Azolla* was cultivated along with rice as a dual crop, it was not incorporated and urea - N was applied to rice at transplanting and at PI stage. In all *Azolla* treated plots, the same phosphorus application methods were practiced. All amount of potasic fertilizer as muriate of potash (KCl) was applied at the amount of 25 kg K_2O/ha at transplanting. Nitrogen as urea and phosphorus as tripple superphosphate were applied at the amount of 37.5 kg/N/ha and 37.5 kg P_2O_5/ha. Nitrogen was only applied in the non - *Azolla* treated plots.

Azolla growth rate and *Azolla* N production rate (kg/ha/day) were determined by sampling the *Azolla* biomass. The following method was used to determine the growth rate and *Azolla* -N production rate:

1. *Azolla* growth rate (kg/ha/day) =

$$\frac{\text{Azolla biomass (fresh wt.)(kg/ha)}}{\text{number of Azolla growing days}}$$

2. *Azolla* N production rate (kg/ha/day) =

$$\frac{\text{total N production (kg/ha)}}{\text{number of Azolla growing days}}$$

$$\text{N (kg/ha)} = \frac{A \times B \times C}{100 \quad 100}$$

Where, A = dry weight of *Azolla* (%)
B = fresh weight of *Azolla* (kg/ha)
C = N content (% N) in *Azolla*

Rice grain yields from all the plots were harvested by sampling from an area of 8.44 m2 excluding 2 border rows. The grain production per kg N application was also determined by mathmatical calculations. Both *Azolla* and rice production parameters were statistically analysed by Least Significant Difference Test (LSD). Net returns obtained by the application of *Azolla* with

Table 1 Treatments of the experiment.

Treatments	Remarks
1. A0N0P0	
2. A1N0P	A0 = *Azolla* was not applied
	A1 = *Azolla* grown 20 days before transplanting and incorporated at transplanting.
	A2 = *Azolla* grown as a dual crop and not incorporated.
3. A1N1P	N0 = urea - N was not applied
	N1 = urea - N (37.5 kg N/ha) applied to rice half at transplanting and the other half at PI.
4. A2N1P	P = 37.5 kg P_2O_5/ha

or without urea - N to rice was compared between the methods used for *Azolla* cultivation. N produced by different *Azolla* cultivation methods was converted into total N gain/ha in terms of money (Baht)(Table 2).

RESULTS AND DISCUSSION

Effects of cultivation methods on *Azolla* (growth rate and N - production rate)

The results presented in Table 2 indicated that *Azolla* growth rate did not differ significantly by its cultivation methods but a slightly higher rate of its growth was observed on *Azolla* cultivated as a monocrop to that with *Azolla* cultivated as a dual crop. An average of 610 kg/ha/day of biomass (fresh weight) or 45.7 kg dry weight/ha/day was produced by *Azolla microphylla.* A similar growth rate (49.4 kg dry wt./ha/day) was reported by Rains and Talley (1979). In another investigation, Cerrato and Romero (1981) studied the *Azolla* in Jensen's medium devoid of N and reported a growth rate of 470 kg fresh biomass/ha/day which was lower than that found in this investigation.

A N - production rate of as high as 1.6 kg N/ ha/day was observed on *Azolla* grown before transplanting which was significantly higher (A1N1P) than the rate produced by *Azolla* grown as a dual crop with rice (Table 2, Figure 1). An average of 1.3 kg N/ha/day of N2 fixation rate was observed in *Azolla microphylla.* A similar fixation rate of 1.2 kg N/ha/day was reported by Talley *et al.* (1977). The results suggested that *Azolla* could be a good source of N required by the rice crop and thus, helped cut down the fertilizer - N requirements of the rice crop regardless of the methods of *Azolla* growing.

Effect of *Azolla* and urea - N on rice (production and return) :

The grain yield data presented in Table 3 indicated that a maximum grain yield of 3679 kg/ ha was produced with *Azolla* grown along with rice (A2N1P) which was supplemented with only a 21.3 kg/ha of *Azolla* - N along with urea - N to rice as compared to that produced (3412 kg/ha) with *Azolla* - N of 33.2 kg/ha at the same level of urea - N (A1N1P). It suggested that the use of *Azolla* along with urea - N to rice helps enhance the effeciency of urea -N resulting in higher grain yield production (Adhikary *et al.*, 1996; Swatdee, 1980). However, no significant difference existed in grain yield production between the both methods employed. But a higher rate of production of grain yield per kg N applied was observed with the *Azolla* grown as a dual crop with rice as compared to that with *Azolla* grown before transplanting and incorporated at transplanting (A1N1P). The rate of

Table 2 Effect of *Azolla* cultivation methods on its production rates.

Treatments	Growth rate (kg/ha/day)	Nitrogen production rate (kg/ha/day)	Total N production in 20 days (kg/ha)	Price of *Azolla* - N* (equivalent to price / kg urea - N)(Baht)
A1N0P	603.0 a	1.29 ab	25.8 ab	403.77
A1N1P	710.5 a	1.60 a	33.2 a	519.58
A2N1P	519.0 a	1.00 b	21.3 b	333.34
Mean	610.0	1.30	26.8	418.89
CV %	47.8	23.00	23.0	

Means followed by a common letter in a column, are not significantly different at 95% level by LSD.
* 1 kg urea - N = 15.65 Baht and 1 kg urea = 7.20 Baht (Source : Choonluchanon,S., Soil Microbiol. Res. Group, Soil Science Division (DOA) - personal communication.

Table 3 Effects of *Azolla* and urea - N on profitable rice yield production.

Treatments	Total N to rice (kg/ha)		Grain yield at 14% moisture		Grain yield over control (kg)	Price of* grains (Baht)	Net return (Baht) (grain price minus urea-N price)
	Azolla-N	Urea-N	(kg/ha)	(kg/ha/kgN)			
A0N0P0	0.0	0.0	2701 c	-	-	-	-
A1N0P	25.8	0.0	3027 bc	12.63	326	1350	1350
A1N1P	33.2	37.5	3412 ab	10.05	711	2994	2407
A2N1P	21.3	37.5	3679 a	16.60	978	4049	3462

Means in a column followed by a common letter, are not significantly different at 95 % level by LSD.
* Price of grains = 4.14 Baht/kg grain (source : Agric.statistics of Thailand, Crop year 1994/95).

increment in the grain yield production (kg/ha/kg N) was found as high as 16.6 kg grains/ha/kg N by the application of *Azolla* and urea - N together compared to that with *Azolla* grown before transplanting (Figure 2) with or without urea - N to rice.

The economical data presented in Table 3 indicated that highest net return was obtained with *Azolla* when grown as a dual crop with rice even if the *Azolla* was not incorporated. This is due to the higher effeciency of urea - N on grain production when applied together with *Azolla* to rice. This finding agrees with the findings of Swatdee (1980). A maximum of 978 kg /ha of additional grains (equivalent to net return of 3,462.0 Baht/ha) was obtained with dual cropped *Azolla* (A2N1P) which was nearly 3 times more than that of *Azolla* alone (A1N0P), and approximately higher by 70 % to

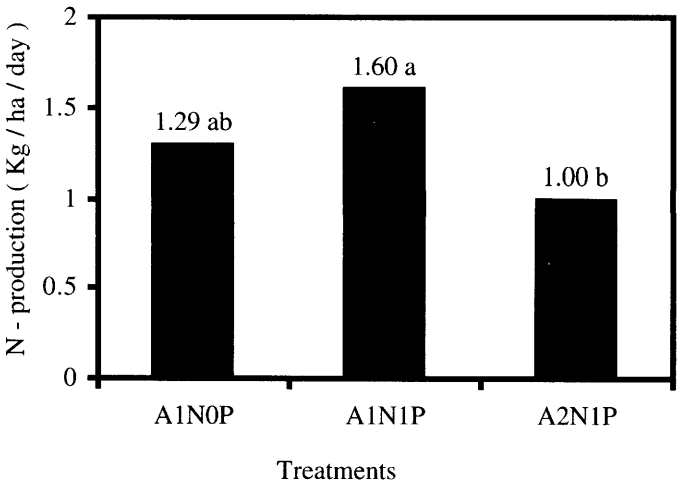

Figure 1 Effect of *Azolla* and urea -N on its N production (kg N/ha/day).

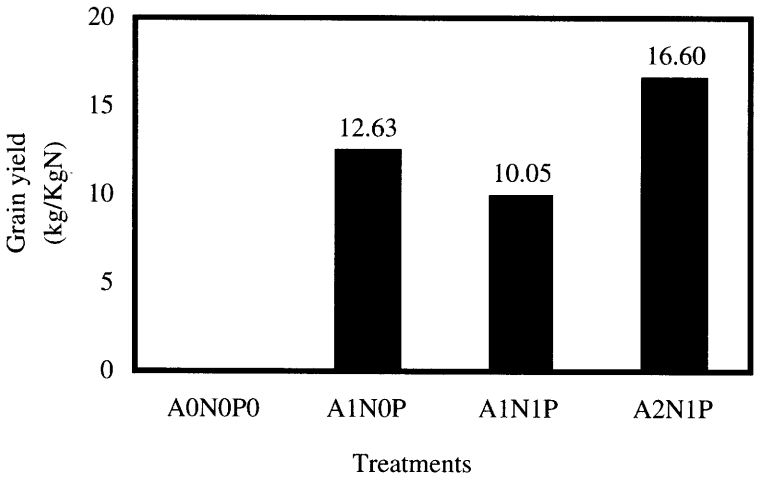

Figure 2 Effect of *Azolla* and urea - N on grain production (kg/kg N).

that produced with *Azolla* grown before transplanting (711.0 kg additional grains, equivalent to net return of 2,407.0 Baht/ha) and incorporated with urea - N application (A1N1P) (Table 3). In this regard, growing *Azolla* as a dual crop with rice seems more economical.

The production data as reported by Agric. Statistics of Thailand (Crop year, 1992/93) indicated that the National average production of rice in Thailand is rather low (2.18 t/ha). The whole Kingdom's irrigated land is approximately 2.4 million hactares which is 27 % of the total rice growing area in Thailand in the year 1987 (IRRI, 1991). On the other hand, the water floating fern, *Azolla* could be introduced in irrigated rice fields which does not cost more as the P requirement of *Azolla* is sufficient to meet the P requirement of rice also (Swatdee and Boonkerd, 1990) and the

rice production can be driven to some extent to higher levels by the introduction of *Azolla* along with or without the application of urea - N to rice regardless of the *Azolla* cultivation practices used in rice production (Adhikary *et al.*, 1996).

CONCLUSION

The research highlights of this investigation can be concluded as follows :

1. Estimates of the total N input of *Azolla* in paddy soils are rather variable because they are influenced by such factors as the agricultural system used for its cultivation. An average production of 610 kg/ha/day of *Azolla* (fresh weight) and 1.3 kg N/ha/day by *Azolla microphylla* could be produced irrespective of the methods of growing used, which indicated a high potentials of the *Azolla* for its use in rice cultivation.

2. The results suggested that the effeciency of urea - N to rice grain yield production was increased by the application of *Azolla* and urea - N applied together. In addition, *Azolla* grown as a dual crop with the application of urea - N to rice gave higher return compared to those of other cultivation practices used.

3. The resullts suggested that the National average of rice yield could be driven to higher levels to some extent by the introduction of *Azolla* in irrigated fields when applied alone or along with urea - N on rice.

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