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Changes in Soil N, P, K, Rice Growth and Yield Following the Application of *Azolla pinnata*

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Abstract

Information on the effects of *A. pinnata* application on changes in nutrient availability and rice yield obtained from paddy fields of the South Lampung, Indonesia is still limited. A study was carried out to investigate the effects of different rates of *A. pinnata* (0; 2.5, 5.0, 7.5, and 10.0 t/ha) on changes in N, P, K concentrations in paddy soils, N uptake, rice growth and yield. The experiment was conducted on a well-irrigated paddy field that was incorporated with *A. pinnata*, and then rice seedlings of Ciherang variety had been grown on it from June up to December 2009. The results showed that the application of *A. pinnata* to the paddy rice fields affected the soil available P, plant height, tiller number, grain number per panicle, and grain yield. The addition of *A. pinnata* at the rate of 5.0 and 7.5 t/ha had higher rice yield compared with other treatments. The application of *A. pinnata* at the rate of 7.5 t/ha increased significantly soil available P, indicating that *A. pinnata* required a fairly high P to grow optimally. The application of *A. pinnata* at the rate of 7.5 t/ha gave also the highest dry grain yield, suggesting that the application of *A. pinnata* did not suppress the rice yield, even it might help to conserve fossil fuels and foreign exchange as well as allow more paddy fields that can be fertilized by N. Practically, the application rate of *A. pinnata* could range 4-8 t/ha, depending on the abundance of the material at the site.

Keywords: *Azolla pinnata*, organic matter, rice growth and yield, soil nutrients

1. Introduction

Like other Asian rice producing countries, Indonesian rice farmers and consumers depend upon the sustainable productivity of the irrigated lowland rice ecosystem for their food supply as 55% of the Indonesia rice is produced in irrigated areas (Buresh *et al*. 2005). Moreover, the demand of rice in the country is increasing in line with the population increased (Sembiring 2011). Therefore, it is imperative to maintain and even to maximise rice production. To maintain paddy soil fertility having a high yield, it is required an adequate supply of organic matter, so the paddy rice soil systems are able to provide satisfactorily available nutrients to the crop sustainably (Sahrawat 2004).

Rice production based on organic applications is growing in interest and the effective use of organic materials in rice farming is also likely to be promoted. However, study of the decomposition of organic matter that observed changes in the chemical properties, particularly the organic matter derived from *Azolla pinnata* is still very limited in Indonesia, especially in South Lampung, Sumatera, as one of rice production centers in Indonesia. The *A. pinnata* is a great source of N in rice ecosystems, due to the symbiosis between the plants and *Anabaena azollae* that can fix N from the air (Singh & Singh 1990). Contribution of N from the plant into the soils is about 60-80 kg N/ha/season (Khan 1983) as well as the addition of organic matter to the soil as a result of the decomposition (Watanabe 1984). Many studies reported that A. pinnata is commonly used as organic fertilizer in cultivation of various crops (Lillian 2000; Pabby *et al*. 2003; Abd El-Rasoul *et al*. 2004). Its utilization as a green manure on agricultural lands can increase the availability of nutrients and soil physical properties, especially to increase soil porosity (Singh & Singh 1990; Choudhary & Kennedy 2004; Ventura & Watanabe 1993).

In South Lampung District, besides the rice straw as an abundant source of organic matter in paddy fields, *A. pinnata* is also available extraordinarily. However, normally the local farmers throw it away from the paddy fields by raising irrigation water surface. Therefore, the objectives of this study were to determine the effects of application of different rates of *A. pinnata* to paddy fields on changes in availability of soil N, P, and K, N uptake, rice growth and yield.

2. Materials and Methods

2.1 Trial Design and Conduct

The experiments were conducted in Kedaloman Village, South Lampung District, Indonesia, from June up to December 2009. Selected chemical properties of the soil are at the trial site is presented in Table 1. In this region, the water is available throughout the year; hence, the trial can be implemented although during the dry season.

Table 1. Selected chemical properties of the paddy rice soil at the trial site

No.	Parameter	Value
1.	pH-H_2O	6,50
2.	pH-KCl	5,41
3.	C-organic (%)	1,29
4.	N-total (%)	0,20
5.	C/N ratio	6,45
6.	Bray-1 P (mg/kg)	2,45
7.	K (cmol/kg)	1,28
8.	Ca (cmol/kg)	3,84
9.	Mg (cmol/kg)	2,61
10.	Na (cmol/kg)	0,03
11.	CEC (cmol/kg)	14,95
12.	Al (cmol/kg)	0,25
13.	Texture: Sand (%)	29,57
	Silt (%)	29,97
	Clay (%)	40,46

The study observed the effect of application of various doses of *A. pinnata*, namely: 0, 2.5, 5.0, 7.5, and 10.0 t/ha. The treatments were arranged in a randomized block design with five replications. The soils were ploughed once and then flooded. Afterwards, *A. pinnata* was sown and buried by trampling and ploughing for the second time. Then the soils were flooded during 21 days. The 14-day old rice seedlings of Ciherang variety were planted with spacing of 30 cm x 30 cm (about 11,000 hills/ha). Each plot size was 4 x 5 m^2. One day after the soils were flooded, the soil and the water were taken for measuring the chemical properties, namely pH, C-organic (Kurmis method), N-total (Kjeldahl method), C/N ratio, N-NH4+ (1 N KCl), available P (Bray I), while, the method of extraction of 1 N NH4C2H4O2 at pH of 7.0 was used to determine exchangeable K, Ca, Mg, and Na, Fe, Mn, and Cation Exchange Capacity (Blakemore *et al*. 1987).

Urea was given three times (1/3 at planting time, 1/3 at 21 days after planting, and 1/3 at panicle initiation time). For the treatment of *A. pinnnata* of 0 and 2.5 t/ha, the rate of urea applied was 250 kg/ha. The rate of urea was 200 kg/ha for the application of *A. pinnata* of 5.0 and 7.5 t/ha. For the application of *A. pinnata* of 10 t/ha, the rate of urea was 150 kg/ha. The SP-36 at the rate of 100 kg/ha was applied once at planting time. While, the KCl at the rate of 100 kg/ha was applied twice (1/2 at planting time and 1/2 at 21 days after planting).

Soil samples were taken to determine N, P, and K concentrations in the soils at the beginning of panicle initiation. Plant samples were taken to measure N uptake, rice growth (plant height and tiller number), and yield (number of grains per panicle, 1,000 grain weight, and grain yield) at the end of the trial.

2.2 Statistical Analysis

Data were subjected to analysis of variance (ANOVA). The Least Significant Difference test (LSD) at p = 0.05, unless otherwise stated, was used to separate the means when ANOVA results indicated there were significant treatment effects (Steel *et al*. 1997).

3. Results and Discussion

3.1 Chemical Properties of A. pinnata

The results in Table 2 showed that in *A. pinnata*, the content of C-organic and N-total were 21.76% and 2.43%, respectively. This suggested that the application of 5.0 t/ha of fresh *A. pinnata* to the paddy soil, for instance, may give 121.5 kg N/ha or equivalent to 264.13 kg urea/ha. Meanwhile, Ferentinos *et al*. (2002) reported that Azolla might produce 39-390 t/ha of dry matter which is equivalent to 53-1,000 kg N/ha fixed.

Table 2. Chemical properties of *A. pinnata*

No.	Parameter	Value (%)
1.	Water content	89,12
2.	pH	6,50
3.	C	21,76
4.	N-total	2,43
5.	P-total	0,17
6.	K	0,77
7.	Ca	0,19
8.	Mg	0,22

3.2 Soil Available N, P, and K

There was no significant difference among the treatments of *A. pinnata* application rates in soil total N, exchangeable K, and N uptake by the rice crops (Table 3). However, at the time of panicle initiation, the application of *A. pinnata* increased significantly the soil available P as measured by Bray-1 P. The addition of *A. pinnata* at the rate of 10 t/ha to the paddy soils increased soil available P by 89%. These results indicated that *A. pinnata* needs a fairly high P to grow optimally. However, after decomposition of *A. pinnata*, according to Watanabe *et al*. (1980), P compounds will be released into paddy soils. Hence, it enhanced soil P fertility to the crops (Singh & Singh 1990; Choudhary & Kennedy 2004).

Table 3. Effects of *A. pinnata* application on the N-total, available P, exchangable K in soils and N uptake

No.	*A. pinnata* (t/ha)	N-tot (%)	Bray-1 P (mg/kg)	Exchangable K (cmol/kg)	N-uptake (g/plant)
1.	0	0.17 a[1]	1.86 a	0.59 a	0.51 a
2.	2.5	0.17 a	2.55 ab	0.54 a	0.46 a
3.	5.0	0.17 a	1.91 a	0.69 a	0.54 a
4.	7.5	0.17 a	1.68 a	0.58 a	0.57 a
5.	10.0	0.18 a	3.17 b	0.63 a	0.64 a
	LSD ($p<0.05$)	ns	1.06	ns	ns

Note: [1]Numbers within the same column followed by the same letters are not significantly different at p<0.05

3.3 Plant Growth and Yield

The results of Least Significant Difference Test in Table 4 revealed that the highest level application of *A. pinnata* (10.0 t/ha) resulted in the highest plant height. Similarly, this application rate gave the highest tiller number per hill as well. It is likely that the increased growth parameters related to the adequate N availability supplied by the incorporated *A. pinnata*. In line with this result, Ferentinos *et al*. (2002) in their study found that N fixed by Azolla ranged from 53-1 000 kg/h which was released 40-60% after 20 days and 55-90% after 40 days of incorporation into paddy field soils.

Table 4. Effect of application of *A. pinnata* on plant height and tiller number per hill

No.	*A. pinnata* (t/ha)	Plant height (cm)	Tiller number/hill
1.	0	72.8 a[1]	38.53 a
2.	2.5	72.7 a	38.34 a
3.	5.0	74.9 ab	37.59 a
4.	7.5	74.3 ab	40.55 ab
5.	10.0	76.7 b	42.57 b
	LSD ($p<0.05$)	3.25	3.30

Note: [1]Numbers within the same column followed by the same letters are not significantly different at p<0.05

Measurements on rice yield components and yield showed that the number of grains per panicle and dry grain yield were affected by the application of *A. pinnata*. Unlike number of grain per panicle and dry grain yield, the 1,000-grain weight was not affected by the application of *A. pinnata*.

The values in Table 5 showed that the highest number of grains per panicle was given by the application of *A. pinnata* at the rates of 7.5 and 10.0 t/ha. There was no difference in grain number per panicle between the two highest rates.

Table 5. Effect of application of *A. pinnata* on the number of grains per panicle, 1,000-grain weight, and grain yield

No	*A. pinnata* (t/ha)	Number of grains/ panicle	1,000-grain weight	Grain yield (t/ha)
1.	0	154.12 a[1]	27.73 a	8.12 ab
2.	2.5	163.92 a	28.07 a	7.93 a
3.	5.0	163.28 a	26.34 a	8.68 ab
4.	7.5	176.60 b	28.13 a	8.84 b
5.	10.0	178.60 b	27.46 a	8.18 ab
	LSD (p<0.05)	9.50	ns	0.9

Note: [1]Numbers within the same column followed by the same letters are not significantly different at p<0.05

The number of grains per panicle increased with increasing the rate of *A. pinnata*. This result most probably because of the improved soil fertility resulted from the decomposition of *A. pinnata* containing marked amount of N-total, C-organic, and available P released (Singh & Singh 1990; Choudhary & Kennedy 2004).

As observed for the number of grains per panicle, the grain yield was affected by the incorporation of *A. pinnata*. The highest grain yield was resulted from the application of 7.5 t/ha of *A. pinnata*. These suggested that the rate of *A. pinnata* that might be applied ranging from 5.0 to 7.5 t/ha. In other words, practically the rate of fresh *A. pinnata* applied could be 4, 6 or 8 t/ha. This result also confirms that there was no evidence that the use of *A. pinnata* as source of paddy soil organic matter would inhibit or suppress the rice growth as the local farmers thought. Normally, the farmers in the study area throw *A. pinnata* away from paddy fields by raising irrigation water surface. For organic farming practices, *A. pinnata* is one of the reliable sources of N, because it contains 2.43% N, which means that by giving 5 t/ha of *A. pinnata*, it can be mined approximately 121.5 kg N/ha or equivalent to 264 kg urea/ha. This amount of urea, indeed, is very meaningful from the view points of fossil fuel saving, foreign exchange as well as the wider areas that can be fertilized by N.

5. Conclusions

Application of *A. pinnata* to the rice paddy fields affected the soil available P, plant height, tiller number, grain number per panicle, and grain yield. The addition of *A. pinnata* at the rate of 5.0 and 7.5 t/ha had higher rice yield compared with other treatments. The *A. pinnata* used had a relatively high N content, ie 2.43%.

The application of *A. pinnata* at the rate of 7.5 t/ha increased significantly soil available P, indicating that *A. pinnata* required a fairly high P to grow optimally. The application of *A. pinnata* of 7.5 t/ha gave also the highest dry grain yield, suggesting that the application *A. pinnata* did not suppress the rice yield, even it may help to conserve fossil fuels and foreign exchange as well as allow more paddy fields that can be fertilized by N. Practically, the application rate of *A. pinnata* could range 4-8 t/ha, depending on the abundance of the material at the site.

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