The effect of organic fertilizer based on *Azollamicrophylla* biomass and plant spacing to n and p uptake, soil compaction and the yield of Pandanwangi rice

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**Abstract.** The objective of the research was to study the effect of using azolla as organic fertilizer and plant spacing toward (i) N and P uptake, (ii) soil compaction and (iii) the yield of Pandanwangi rice. The research was conducted using Completely Block Randomized Design (CRBD) with 6 replicates of 2 factors combination. The first factor was doze of Azolla organic fertilizer consisted two levels were 2.5% and 5% of soil weight. The second factor was plant spacing consisted of three levels were 25cm × 25cm, 30cm ×30cm and 40cm × 40cm.  Data was analysed by F test and if there were any significant effects then it was continued by using Duncan’n Multiple Range Test (α=5%). The result of this research showed that application of azolla organic fertilizer as much 5% of soil weight was able to increase N uptake and weight of grain per hill. The application of azolla organic fertilizer to all doze treatments was also able to reduce the soil compaction. The largest of plant spacing treatments was able to increase (i) N and P uptake, and (ii) weight of grain per hill.

1. **Introduction**

Most of paddy field in Indonesia have problems in levelling off the productivity [1] that can be caused due to the use of chemical fertilizer constantly. The excessive use of it can lead the soil compaction. Soil compaction can affect the root penetration by inhibiting root development which is caused due to reduce of soil ability to absorb water and provide sufficient oxygen for it [2]. One of the efforts to overcome these problem is using organic fertilizer which is obtained from local organic matter.

System Rice of Intensification (SRI) is an organic rice cultivation technology that emphasizes the management of soil, plant and water based on local wisdom. One of managements of plant is plant spacing arrangement. Plants that grow at wider plant spacing have larger areas of nutrient intake and solar light gain that used in the photosynthesis process [3]. Rice plant spacing arrangement at wider spacing (at the case: 25cm × 25cm) was able to increase the yield of grain compared with a narrow spacing. Soil management can be done with the use of local organic fertilizers to reduce soil damage due to the use of chemical fertilizers. Some local organic fertilizers that’s easy to be found are farmyard manure, straw, corn stover and green manure (such as Azolla) [4].

Azolla is a water nail plant that is very potential to be developed as organic fertilizer either as a green manure or made as compost [5] especially as N fertilizer. The N content of *Azollamicrophylla* is 0.03–0.66 % [6]and it is smaller than N content that have been reported by [7], i.e 2.80–3.04 % on same species. In the appropiate condition, Azolla can supply the need of N rice plant as much 50–100 kg N within 10–20 days [8]. The use of Azolla fertilizer that’s combined with farmyard manure and azolla as a dual cropping with rice plant can improve the productivity of plants [9]. The use of Azolla
compost in Kangkong plant [10] and Pakcoy plant [11] was able to obtain growth rate and yields that’s equivalent to the use of urea fertilizer.

Recent studies has discovered that using azolla as organic fertilizer and it’s with various fertilizer have influence the rice growth and yield, but application of azolla fertilizer in various plant spacing on rice plant is seldom investigated. Thus, the objective of the research was to study the effect of using azolla as organic fertilizer and plant spacing toward (i) N and P uptake, (ii) soil compaction and (iii) the yield of Pandanwangi rice.

2. Materials and Methods

2.1. Greenhouse experiment

The research was conducted by planting rice in controlled environment greenhouse from 2010–2011. The soil material was taken from a conventional paddy field in Karangwangkal Village, Purwokerto, Central Java, by applying composite top soil 0–20 cm. The soil material was dried and sived diameter 2 mm. The soil type was Inceptisol with chemical characteristic: pH 6.46; 2.64 % Organic-C; 0.26 % total-N, 90 ppm available N; 4.51 ppm available P; bulk density = 1.17 g cc\(^{-1}\).

The organic fertilizer was made locally based on 60% of fresh Azollamicrophylla biomass, and 40 % of it consisted of 11.5 % of cattle dung, 20% of broiler dung, 8 % of banana cobs and 0.5 % of straw. The materials was semi-anaerobic processed. The pot *Albasia* sp. wood was made as the represented of plant spacing of 25cm × 25cm, 30cm × 30cm and 40cm × 40cm and the deep of it was 40 cm.

The experiment used Completely Randomized Block Design (CRBD) with six replicates of two factors combination. The first factor was doze of Azolla organic fertilizer consisted two levels were 2.5% (Af 1) and 5% (Af 2) of soil weight. The second factor was plant spacing consisted of three levels were 25cm × 25cm (Ps 1), 30cm × 30cm (Ps 2) and 40cm × 40cm (Ps 3). Thus, the experiment had the following treatment: Af 1 + Ps 1, Af 1 + Ps 2, Af 1 + Ps 3, Af 2 + Ps 1, Af 2 + Ps 2 and Af 3 + Ps 3.

The plot experimental unit used 32.45 kg of soil on Ps 1, 46.7 kg of soil on Ps 2 and 83 kg of soil on Ps 3 (18 % air dried water content). Fourteen days before transplanting, azolla fertilizer was applied, evenly mixed into the soil. The rice was planted by SRI method in deep mud of Inceptisol potted; the 12-days young rice was transplanted with L-shape and one seedling per hill. The plants were harvested at maturity 96 days after transplanting (DAT).

2.2. Fertilizer, soil and plant parameter measurement

The quality of Azolla fertilizer was measured based on some parameter, i.e Organic-C, total of N, P\(_{2}\)O\(_5\), K\(_2\)O, C/N and pH. Bulk Density (BD) was used as the soil parameter to measure the soil compaction. Weight of grain per hill (WGH), that is the weight of grain per hill after remove from the straw, was used as the yield of plant parameter.

2.3. Statistical analysis

The analysis of variance was used to discover the difference of influences in treatments and whether there is a significant difference, followed by Duncan's Multiple Range Test (α=5%). Correlation analysis was used to determine the relationship between nutrient uptakes (N-P) and yield (weight of grain per hill). All statistical analyses used SPSS Statistics 20.0 software.

3. Results and Discussion

3.1. Azolla fertilizer characteristic

The total organic C and N of Azolla fertilizer were 27.84 % and 2.09 %, respectively resulting in a C/N ratio of 12.84. Based on C/N value of Azolla fertilizer that’s showed in table 1, the azolla fertilizer was matured suitable for the research purpose. Some studies reported that C/N value of
mature organic fertilizer are 10–20[12, 10]. Mature organic fertilizer are safe to be used and effect to crops. In addition, maturity of organic fertilizer indicated the presence or absence of phytotoxins[13]. The pH value of Azolla fertilizer (7.38) showed that it would not decrease the soil pH. The total-N of Azolla fertilizer (2.09 %) was less than 6 %, 50–75 % of it was organic N, and the residue of it (25–50 %) was NH₄[14].

Table 1.Characteristic of Azolla fertilizer.

| Organic fertilizer | Organic-C (%) | N (%) | C/N | P₂O₅ (%) | K₂O (%) | pH |
|--------------------|---------------|-------|-----|----------|---------|----|
| Af                 | 26.84         | 2.09  | 12.84 | 2.48     | 0.65    | 7.38 |

3.2. N and P uptake by Pandanwangi rice
The N uptake of the rice were significantly different at the Azolla fertilizer the treatments (table 2). Azolla fertilizer application at the higher doze (Af 2) resulted in increased of N uptake, but it was not significant in increased of P uptake. Although the average of P uptake at Azola fertilizer was not significant, but there was a tendency that the use of Azolla fertilizer could increase the P uptake. Decomposition process of Azolla fertilizer can increase the soil microorganism activity, so thus it can increase the nutrient availability in the soil and nutrient uptake by rice. Azolla fertilizer increased the content of NH₄⁺ and NO₃⁻ in the soil. It showed that Azolla fertilizer was potential to be developed as organic fertilizer [9].

Table 2.Effect of Azolla fertilizer treatment on N uptake, P uptake, BD and WGH.

| Azolla fertilizer | N-Uptake (mg/100 g) | P-Uptake (mg/100 g) | BD (g/cc) | WGH (g) |
|-------------------|----------------------|----------------------|-----------|---------|
| 2.5               | 155.71ᵇ               | 18.00                | 0.94      | 66.87ᵇ  |
| 5.0               | 210.57ᵃ               | 18.09                | 0.97      | 80.45ᵃ  |

Numbers at the same column followed by the same letter or without letter were not significantly different by DMRT 5% level, BD = Bulk Density, WGH = Weight of Grain Yield.

Plant spacing treatments gave different result of N and P uptake (table 3). The widest treatment (Ps 3) gave the highest uptake of N (259.96 mg N/100 g) and P (24.22 mg P/100 g). This was due to the root development at the wider space is better than the narrow one, thus it could absorb nutrient optimally [3,15]including N and P uptake by rice. This was in contrast to the studies conducted by [16] and other researchers, who found that the highest of NPK uptake under SRI for some varieties didn’t obtain at the widest spacing, but it was in optimum spacing. The optimum plant spacing ensured plants to grow properly both in their aerial and underground parts through different utilization of solar radiation and nutrients [17].

Table 3.Effect of plant spacing treatment on N uptake, P uptake, BD and WGH.

| Plant Spacing | N-Uptake (mg/100 g) | P-Uptake (mg/100 g) | BD (g·cc⁻¹) | WGH (g) |
|---------------|----------------------|----------------------|-------------|---------|
| 25 cm × 25cm  | 127.59ᵇ               | 13.47ᵇ               | 0.93        | 53.93ᵇ  |
| 30 cm × 30cm  | 168.67ᵇ               | 16.44ᵇ               | 1.03        | 65.76ᵇ  |
| 40 cm × 40cm  | 259.96ᵃ               | 24.22ᵃ               | 0.90        | 101.29ᵃ |

Numbers at the same column followed by the same letter or without letter were not significantly different by DMRT 5% level, BD = Bulk Density, WGH = Weight of Grain Yield.
Table 4. Effect of the combination treatment on N uptake, P uptake, BD and WGH.

| Treatment                  | N-Uptake (mg/100 g) | P-Uptake (mg/100 g) | BD (g·cc⁻¹) | WGH (g) |
|----------------------------|----------------------|----------------------|-------------|----------|
| 2.5% Af + 25 cm × 25 cm    | 89.25                | 12.77                | 0.86        | 46.69    |
| 2.5% Af + 30 cm × 30 cm    | 157.74               | 15.41                | 0.94        | 60.19    |
| 2.5% Af + 40 cm × 40 cm    | 165.94               | 25.81                | 1.01        | 93.73    |
| 5.0% Af + 25 cm × 25 cm    | 179.61               | 14.17                | 0.99        | 61.17    |
| 5.0% Af + 30 cm × 30 cm    | 217.23               | 17.48                | 1.12        | 71.33    |
| 5.0% Af + 40 cm × 40 cm    | 302.68               | 22.63                | 0.79        | 108.86   |

Numbers at the same column followed by the same letter or without letter were not significantly different by DMRT 5% level, BD = Bulk Density, WGH = Weight of Grain Yield, Af = Azolla fertilizer.

Table 4 showed that the WGH was not significantly different at the combination treatments. Although the average of WGH was not significant, but there was a tendency that the addition of Azolla fertilizer application and the increasing of plant spacing could increase WGH of Pandanwangi rice. The highest of WGH (108.86 g) was obtained at the treatment with 5.0 % Af addition at the widest plant spacing (40cm × 40cm).

![Figure 1. Correlation between N-Uptake and WGH.](image-url)
Table 5. Correlation between N-P Uptake and Weight Grain per hill.

|            | Correlation | R-Square |
|------------|-------------|----------|
| N-Uptake   | 0.85**      | 0.660    |
| P-Uptake   | 0.75**      | 0.899    |

Table 5 showed that there was correlation between WGH and N-uptake (0.85**) and P-uptake (0.75**) of the experiment was significant. That correlation between N-uptake and WGH was also showed at figure 1. The increasing of N-uptake at Azolla fertilizer (table 2) and plant spacing treatment (table 3) affected WGH with $r^2 = 0.660$ (table 5). The correlation between P-uptake and WGH was also at figure 2. The increasing of P-uptake at the plant spacing treatment (table 3) affected WGH with $r^2 = 0.899$ (table 5), although P-uptake of the rice was not significantly different at the Azolla fertilizer treatment (table 2). The correlation suggest that the use of Azolla fertilizer at the various plant spacing was able to increase N-P uptake, so thus it affected WGH.

4. Conclusion
The experiment found that the Azolla fertilizer is potential to be developed as the organic fertilizer to reduce the use of chemical fertilizer to rice plant. The use of Azolla fertilizer can increase N-uptake and weight grain per hill of Pandanwangi rice. The wider plant spacing will increase N-P uptake and weight grain per hill. The experiment also found that Azolla fertilizer is potential as soil amandement. It can decrease the BD value, so thus it can decrease the soil compaction.

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