Influence of goat manure and Azolla on soil properties, nitrogen use efficiency, growth and yield of organic rice farming in Indonesia

R C Putra¹, S N Hidayah¹, B H Purwanto¹
¹Department of Soil Science, Faculty of Agriculture, Universitas Gadjah Mada, Jl. Flora No.1, Bulaksumur, Yogyakarta, Indonesia

Abstract. Application of organic fertilizers plays an important role in increasing nutrient availability to plants. However, external sources of C in organic farming must originate from nonsynthetic materials such as organic fertilizers or soil amendments. Goat manure and azolla green manure are widely available sources of organic fertilizers in the farmers village. The study was aimed to observe the effect of combined fertilizers dose of azolla and goat manure on N efficiency and to find the optimum dose of the fertilizers which gives the best rice growth and production. The experiment was located in farmers field of Sambirejo, Sragen, Indonesia. A completely randomized block design was implemented in the experiment with treatments of combined fertilizer dose between Azolla and goat manure. The treatments were: K₀A₀, K₀A₁, K₁A₀, K₁A₁, K₂A₀, K₂A₁; which is K: goat manure; A: Azolla (0 means 0 t/ha, 1 means: 3 t/ha, 2 means: 6 t/ha). The results showed that combined treatment of K₂A₀and K₂A₁ produced highest N use fertilizer efficiency. No significant differences were found among the rice yield after the treatments, however treatment of K₂A₀ showed the optimum rice yield (6.8 t/ha).

1. INTRODUCTION
Inorganic fertilizers today hold the key to the success of the crop productions systems in Indonesia agriculture, contributing about 40-50% of the total yield. Although there has been an increasing trend in the consumption of chemical fertilizers, their application appears to be unbalanced since nitrogen alone constitutes about 73% of the total nutrients used in the country, while the other nutrients use is very low. The positive role of organic residues, including green manures on soils and crops have been well documented [1, 2]. Available reports indicated that most soils of Indonesia have a low organic matter content. About 70% of the net cultivable area in high and medium-high lands has a soil organic matter content less than 2% [3]. The organic component is important for nutrition because it serves as a reservoir of nutrients for plants and provides nutrients for soilborne organisms.

The foundation of organic farming lies in the health of the soil. A fertile soil provides essential nutrients to a growing crop plant and helps support a diverse and active biotic community. Strategies the transitional farmer will employ to build the soil are crop rotations, animal and green manures, and cover cropping. Animal manures traditionally have been used to fertilize soils of both organic and sustainable farms. Manure can be applied to the field in either raw or composted form. When a green plant is incorporated into the soil, it has high amounts of nitrogen and moisture and becomes a food source for soil microorganisms and earthworms. During the process of decomposition by the organisms in the soil, organic matter and nutrients become available to the crop plants. An additional benefit from using green manures is the suppression of weeds and soil borne diseases.
Nitrogen use efficiency of crops can be used as a measure of reducing N fertilization rate, achieving optimum yield, as well as minimizing environmental consequence related to nitrate leaching [4, 5]. Many studies have been conducted to estimate NUE [6]. There are some indexes of N use efficiency, i.e.: internal efficiency (IEN) which is the amount of grain yield produced by per kg plant nutrient accumulation in aboveground dry matter, physiological efficiency of applied N (PEN), which is increase yield (kg) per kg increase in N uptake from fertilizer-N, agronomic efficiency of applied N (AEN) which is increase in grain yield per N applied, and recovery efficiency of applied N is explained as the percentage of N applied recovered in above ground biomass [7]. These efficiencies may differ within the same crop because they depend on different organs and mechanisms and on different environmental factors as well [4].

Reduction in environmental load such as application of excess fertilizers and increasing N use efficiency under agricultural production has been suggested for sustainable agriculture [8]. In paddy rice production, the appropriate nutrient application, improvement of nutrient efficiency, utilization of organic materials instead of chemical fertilizers, and so on are possible choices for the sustainable agriculture. To develop more sustainable cropping systems, management systems which maintain and even improve soil organic matter levels need to be developed. Manure and Azolla are organic materials available in the field, and are potential to be used as substitutes with cow dung, however the effect of both type of organic materials on rice growth should be studied. This present study aimed to determine the influence of goat manure and azolla combination as organic fertilizers on nitrogen use efficiency and rice yield to get more sustainable cropping systems in organic rice farming.

2. MATERIALS AND METHODS
The research was conducted at Sambirejo, Sragen, Central Java, Indonesia. The research was conducted in farmer rice field manage organically since 2003. Soil characteristics of the research site are presented in Table 1. The research was conducted during the rainy season of 2013. A completely randomized block design was used with combination of goat manure and Azolla treatments. The treatments were: K_0A_0, K_0A_1, K_1A_0, K_1A_1, K_2A_0, K_2A_1 which is K: goat manure; A: Azolla (0 mean 0 t/ha, 1 means: 3 t/ha, 2 means: 6 t/ha).

Soil chemical analyses included: pH (H_2O) dan pH (KCl), EC, organic C (Walkey and Black), total N, CEC, available P, available K, available N. Nutrients content of goat manure and azolla were also analysed before application. N fertilizer efficiency was calculated by for, rice growth and yield were measured after treatment.  

\[
\text{Nitrogen Use Efficiency} = \left( \frac{N_1 - N_0}{N} \right) \times 100 \%
\]

\(N_1 = \) plant uptake of nutrient after treatment
\(N_0 = \) plant uptake of nutrient before treatment
\(N = \) amount of nutrient applied

2.1. Statistical analysis
The obtained data were subjected to analysis of variance (ANOVA) to compare the effects of sites with different annual rainfall and soil management on earthworms’ assessment variables. The DMRT procedure was used to separate the means of earthworm parameters at \(p = 0.05\).

3. RESULTS AND DISCUSSION
3.1. Chemical characteristics of soil, goat manure and Azolla
Result of soil analysis is shown in Table 1, which is characterized by slightly acid pH, very low EC, medium organic C and total N, a very high of NH_4, NO_3 and available P and medium available K. Soil CEC is generally influenced by soil organic matter content, as well as the amount and type of clay minerals. It is indicated that there were no soil chemical constraints to support plant growth.
Table 1. Chemical Properties of Soils

| Chemical Properties     | Value | Level       |
|-------------------------|-------|-------------|
| pH H₂O                  | 6.01  | Slightly acid |
| pH KCl                  | 4.38  | -           |
| EC (dS.m⁻²)             | 0.09  | Very low    |
| Organic C (%)           | 2.20  | Medium      |
| CEC (cmol⁺(kg⁻¹))       | 24.24 | Medium      |
| Total N(%)              | 0.25  | Medium      |
| NH₄(µg.g⁻¹)             | 65.14 | Very high   |
| NO₃(µg.g⁻¹)             | 83.75 | Very high   |
| Available P(µg.g⁻¹)     | 31.42 | Very high   |
| Available K(cmol⁺(kg⁻¹))| 0.31  | Medium      |

Table 2 showed that goat manure which was used as organic fertilizer has a higher moisture content, C/N ratio and total K content, but lower total P content than azolla. With a lower C/N ratio, azolla is more easily decomposed compare goat manure so that its nutritional content is more readily available to the plant.

Table 2. Chemical Properties of Goat manure and Azolla

| Chemical Properties     | Goat manure | Azolla |
|-------------------------|-------------|-------|
| Moisture content( %)    | 40.16       | 16.63 |
| pH H₂O                  | 8.5         | 8.1   |
| pH KCl                  | 6.7         | 6.8   |
| EC (dS.m⁻²)             | 3.4         | 2.5   |
| Organic C (%)           | 30.06       | 31.38 |
| CEC (cmol⁺(kg⁻¹))       | 54.05       | -     |
| Total N(%)              | 1.49        | 1.98  |
| C/N Ratio               | 20.31       | 15.77 |
| Total P(%)              | 0.56        | 1.10  |
| Total K(%)              | 3.58        | 1.22  |

3.2. Soil Characteristics after treated with goat manure and Azolla

Table 3 showed the soil characteristics after treated with goat manure and azolla. The table showed that there were no significant influences of goat manure and azolla application on soil pH, soil CEC, EC and available P. Soils treated with K₂A₁ showed a significant increase of organic C, total N and available K compared to K₀A₀. It is indicated that treatment of K₂A₁ has improved the soil nutrient content especially organic C, N and K.
Table 3. Soil characteristics after treated with goat manure and Azolla

| Treatments | pH   | Organic C (%) | CEC cmol(+) kg⁻¹ | EC (dS.m⁻²) | Total N (%) | Available P (µg.g⁻¹) | Available K Cmol(+)kg⁻¹ |
|------------|------|---------------|-------------------|-------------|-------------|-----------------------|------------------------|
| K₀A₀: no manure, no Azolla | 6.14a | 3.90b | 24.32a | 0.093a | 0.25b | 32.67a | 0.35a |
| K₀A₁: no manure + 3 tons/ha Azolla | 6.25a | 4.17b | 25.36a | 0.087a | 0.25b | 32.99a | 0.45a |
| K₁A₀: 3 tons.ha⁻¹ manure, no Azolla | 6.29a | 4.10b | 24.96a | 0.087a | 0.26b | 34.55a | 0.48a |
| K₁A₁: 3 tons.ha⁻¹ manure + 3 tons.ha⁻¹ Azolla | 6.19a | 4.50ab | 25.84a | 0.076a | 0.26b | 35.18a | 0.55ab |
| K₂A₀: 6 tons.ha⁻¹ manure, no Azolla | 6.23a | 4.84a | 25.12a | 0.094a | 0.26ab | 35.5a | 0.57ab |
| K₂A₁: 6 tons.ha⁻¹ manure + 3 tons/ha Azolla | 6.22a | 4.84a | 25.92a | 0.074a | 0.28a | 35.81a | 0.60b |

3.3. Growth and yield of rice

Application of Goat manure and azolla did not significantly increase shoots and roots weight, and plant height, except treatment K₂A₁, which has increased significantly plant height compared to K₀A₀ (table 4). Plant height is often observed both as an indicator of growth and as a parameter used for environmental influences. Increase of plant height may be due to the increase of plant metabolism influenced by improvement of nutrient availability in soil after treatments (table 3).
Table 4. Influence of goat manure and Azolla on plant height, shoot weight, and root weight of rice

| Treatments                          | Shoots weight (g) | Roots weight (g) | Plants height (cm) |
|-------------------------------------|-------------------|------------------|-------------------|
|                                     | Wet weight | Dry weight | Wet weight | Dry weight |                      |
| K₀A₀: no manure, no Azolla          | 65.63      | 35.79      | 26.42      | 19.65      | 84.53              |
| K₀A₁: no manure + 3 tons/ha Azolla | 65.85      | 36.18      | 26.49      | 20.46      | 84.53              |
| K₁A₀: 3 tons/ha manure, no Azolla  | 68.43      | 38.82      | 27.01      | 21.59      | 89.80              |
| K₁A₁: 3 tons/ha manure + 3 tons/ha Azolla | 67.06 | 34.34      | 28.12      | 20.38      | 87.60              |
| K₂A₀: 6 tons/ha manure, no Azolla  | 71.36      | 39.03      | 31.51      | 23.42      | 88.93              |
| K₂A₁: 6 tons/ha manure + 3 tons/ha Azolla | 79.46 | 40.40      | 32.31      | 25.48      | 95.53              |

N shoots, N roots, and total N uptake of rice plants has increased significantly after treated with K₂A₀ and K₂A₁ (table 5). This result indicated that higher available nutrients as shown in table 3 had a positive impact on increase of plant total N uptake. N availability in the soil determines the amount of nitrogen that can be absorbed by plants. Total of N uptake of the rice plant in this research was considered low despite the noticeable increase in N uptake after goat manure and azolla applications. The value of N uptake of rice plants was not as large as that reported by [9].

Table 5. Influence of goat manure and azolla on N shoots, roots and total N uptake of rice

| Treatments                          | N shoots (g) | N roots (g) | total N uptake (g/crop) |
|-------------------------------------|--------------|-------------|-------------------------|
|                                     | N content (%) | N uptake (g/crop) | N content (%) | N uptake (g/crop) |                      |
| K₀A₀: no manure, no Azolla          | 0.51         | 0.184       | 0.41         | 0.081         | 0.265             |
| K₀A₁: no manure + 3 tons/ha Azolla  | 0.58         | 0.210       | 0.52         | 0.106         | 0.320             |
| K₁A₀: 3 tons/ha manure, no Azolla   | 0.54         | 0.210       | 0.48         | 0.105         | 0.315             |
| K₁A₁: 3 tons/ha manure + 3 tons/ha Azolla | 0.65  | 0.225       | 0.54         | 0.110         | 0.335             |
| K₂A₀: 6 tons/ha manure, no Azolla   | 0.68         | 0.264       | 0.61         | 0.142         | 0.406             |
| K₂A₁: 6 tons/ha manure + 3 tons/ha Azolla | 0.73  | 0.296       | 0.63         | 0.160         | 0.456             |
Table 6 showed that there were no significant influence of goat manure and azolla application on rice yield, although the rice yield value showed a slight increase on K₂A₀ compared to K₀A₀(0.64 ton.ha⁻¹). The absence of significant differences between treatments may be related to favorable environments and sufficient nutrients content to assure rice crops to grow properly (table 1). The location of the research has been developed for organic farming for 10 years so the soil organic content to assure rice crops to grow properly.

Table 6. Influence of goat manure and azolla on N use efficiency and rice yield

| Treatments                        | N added (kg) | N efficiency (%) | Rice Yield (tons.ha⁻¹) |
|-----------------------------------|--------------|------------------|------------------------|
| K₀A₀: no manure, no Azolla         | -            | -                | 5.69 *                 |
| K₀A₁: no manure + 3 tons/ha Azolla tons.ha⁻¹ | 59.4         | 90               | 5.97 *                 |
| K₁A₀: 3 tons.ha⁻¹ manure, no Azolla | 47.7         | 100              | 6.33 *                 |
| K₁A₁: 3 tons.ha⁻¹ manure + 3 tons.ha⁻¹ Azolla | 107.1        | 60               | 6.25 *                 |
| K₂A₀: 6 tons.ha⁻¹ manure, no Azolla | 95.4         | 140              | 6.78 *                 |
| K₂A₁: 6 tons.ha⁻¹ manure + 3 tons.ha⁻¹ Azolla | 154.8        | 120              | 6.86 *                 |

4. CONCLUSION

Addition of 6 ton.ha⁻¹ goat manure and 3 ton.ha⁻¹ Azolla had increased organic C, total N and available K, N shoots, N roots, and total N uptake of rice plantshas increased significantly after treated with K₂A₀ and K₂A₁. There were no significant influence of goat manure and azolla application on rice yield, although the rice yield value showed a slight increase on K₂A₀ compared to K₀A₀(0.64 ton.ha⁻¹), however K₂A₀ showed the highest N use efficiency.

References

[1] Sutanto 2002 Organic Agriculture: Become Continue and Alternative Agriculture (in Indonesian language) (Yogyakarta Indonesia: Kanisius) p 218
[2] FAO2005Fertilizer used by crop in Indonesia (FAO: Rome)
[3] SetyoriniD, Saraswati Rand Anwar EK 2006 Compost, Organic Fertilizer and Bio Fertilizer. in SimanungkalitRDM, Suriadikarta DA, Saraswati R, Setyorini D, Hartatik W (Eds). Organic Fertilizer and Bio Fertilizer (Indonesian Center for Agricultural Land Resources Research and Development: Bogor)
[4] Benincasa P, Guiducci Mand Tei F 2011The Nitrogen Use Efficiency: Meaning and Sources of Variation (Central Italy: HortTechnology)
[5] ChenG, Chen Y, Zhao G, Cheng W, Guo S, Zhang H and Shi W 2015 Agr.Ecosyst. Environ.209 26–33
[6] Dobermann A and Kenneth GC 2005 Suppl 248 745–758
[7] Sheng-guoC, Bing-qiang ZL, Yan-tiangY, Liang L, Wei L, Zhi-an H, Shu-wen and Bing S 2015 J. Integr.Agr.12 2466–2466
[8] Fan MS, Shen JB, Yuan LX, Jiang RF, Chen XP, Davies WJ and Zhang FS 2012J. Exp. Bot.6313–24
[9] Nishikawa T, Li TK and Inamura T 2014 Plant Prod. Sci.17237–244