Effect of organic fertilizer on nitrogen uptake and yield of two different rice varieties in inceptisol, Kalitirto

D A Ardiantika1, B H Purwanto1* and S N H Utami1

1Department of Soil Science, Faculty of Agriculture, Universitas GadjahMada
*Email: benito@ugm.ac.id

Abstract. Nitrogen is the most limiting element for organic crop production. Hence, application of organic fertilizer is one of the key factors to enhance productivity and improve soil quality, especially in organic farming. The aim of this study was to evaluate the effect of organic fertilizer application on Nitrogen uptake and yield of two different rice varieties. Field experiment was conducted using Randomized Completely Block Design (RCBD) with two factors and three replications. The first factor was various fertilizers (P) i.e Neem cake \textit{(Azadirachta indica)} 5 tons ha$^{-1}$, \textit{Azollamicrophylla} 5 tons ha$^{-1}$, cow manure 5 tons ha$^{-1}$ and inorganic NPK fertilizer 225 Kg ha$^{-1}$ as a comparison. Second factor was rice varieties (V) i.e var. Ciherang and var. MenthikSusu. Plots without fertilizer treatments were served as control. The results showed that treatments were not significantly affected N available and N uptake. Higher Nitrogen uptake and grain yield were showed by Neem cake and var. MenthikSusu. With considerably high Nitrogen uptake and rice grain yield, combination between Neem cake and rice var. MenthikSusu have a prospect as a solution to maintain soil quality and yield in organic farming.

1. Introduction
Rice is a staple food for most people in Indonesia. Therefore, rice in Indonesia perform as benchmarks to measure their success in governing, hereby, people interpret food self-sufficiency as rice self-sufficiency. During 2010-2014, rice production increased on average by 1.63% year$^{-1}$. The rate of rice production was triggered by increasing in harvested area of 540 thousand ha and productivity of 1.20 kwintal ha$^{-1}$ [1]. Recent estimates showed that rice yield must be increased in Asia by about 25% from 2000 to 2020 with the increased yield of 4.9 t/ha from the present yield of 3.9 t/ha for meeting the demand of increased population [2].

Nitrogen (N) is an essential element of crop nutrition and an indispensable input for sustainability of agriculture [3] in the tropics. Nitrogen management presents a major challenge for organic rice growers. Since rice is a staple grain crop there has been significant research done on N fertility as relates to its production, the importance of N management is well documented [4].

Soil N-NH$_4^+$ and N-NO$_3^-$ dynamics are strongly affected by environmental conditions, rate of fertilizer application, and field management. As N enters the soil in the form of organic residues, it is converted to a mineralized form which may enter the soil mineral N pool, be immobilized by microbial biomass, or become available to plants. Mineralized N taken up by plants comes from soil native N pools as well as from organic residues/fertilizers that have mineralized [5] observed there was the significant variation of N uptake among the varieties of rice. Varietals differences might be due to their difference in genetic make-up. Different varieties of rice may have varying responses to N fertilizer depending on their agronomic traits. Therefore, the objectives of the study was to determine the effect of organic fertilizer and rice varieties on N available and N rice uptake.
2. Materials and Methods

2.1. Site Description and Study Design
The field experiment was held at Pusat Inovasi AgroTeknologi (PIAT) Kalitirto, Sleman, Yogyakarta. Bulk surface soils (0–20 cm) were collected from PIAT, Kalitirto before treatments application for the purpose soil selected properties analysis before incubation. The results were showed in Table 1. The investigated soils are ‘non calcic brown soils’ according to. These correspond to the Inceptisols of the USDA Soil. Acidity was 6.3 and categorized as slightly acid. Soil organic carbon was low that is 1.32%. Total nitrogen was in low level that was 0.12%. Available phosphorus was very low that is 3.5 mg kg\(^{-1}\). Exchangeable potassium was very low that is 0.4 cmol(+) kg\(^{-1}\). Soil cation exchange capacity scored low level that is 11.91 cmol(+) kg\(^{-1}\).

| Type of Analysis | Unit | Value | Score |
|------------------|------|-------|-------|
| Tekstur          | %    | 61    |       |
| - Sand           | %    | 61    |       |
| - Loam           | %    | 23    | Sandy Loam |
| - Clay           | %    | 13    |       |
| pH H\(_2\)O      | -    | 6.3   | Slightly acid |
| Organic carbon   | % (w/w) | 1.32 | Low |
| Total Nitrogen   | % (w/w) | 0.12 | Low |
| N-N\(_4\)\(_\)      | mg kg\(^{-1}\) | 3.92 | Low |
| N-N\(_4\)\(_+\)    | mg kg\(^{-1}\) | 3.61 | low |
| Available P      | mg kg\(^{-1}\) | 3.5  | Very low |
| Exchangeable K   | cmol(+) kg\(^{-1}\) | 0.4  | Very low |
| Cation Exchange Capacity | cmol(+) kg\(^{-1}\) | 11.91 | Very low |

Note: * Score was based on Balittanah (2009), w/w = weight per weight

The experiment was conducted using a factorial experiment laid out in a randomized complete block design (RCBD) with three replications consisting of a total of 30 treatments. Treatments consisted the type of organic fertilizer and rice varieties, included control or without organic fertilizers added (P0); Neem Cake fertilizer (5 tons ha\(^{-1}\)) (P1); Azollamicrophylla (5 tons ha\(^{-1}\)) (P2), Cow manure (5 tons ha\(^{-1}\)) (P3) and NPK fertilizer (225 kg ha\(^{-1}\)) (P4). Rice varieties treatments included Ciherang (V1) and Menthik Susu (V2). The field was oxen plowed before laying the experimental plots on the field. A 3m×3m (9m\(^2\)) plot size was used as an experimental unit.

2.2. Crop harvesting, Sample Collection and Analysis
Ciherang and Menthik Susu were harvested in different time harvesting 105 and 125 days after planting (DAP), respectively. These samples were air-dried and then oven dried at 80°C for 48 hour. Oven-dried samples were milled into fine powder and used for chemical analysis. Dry Grain Harvest (DGH), that is the weight of a grain after removed from the straw. Grains harvested from each plot area were dried and weighed and expressed as kg ha\(^{-1}\). Soil samples were collected by using zig zag sampling pattern with three point each plot a depth of 0-20 cm and composited. These sample were airdried and sieved into <0.5 mm and <2 mm.

Nitrogen available as ammonium (N-N\(_4\)\(_+\)) and nitrate (N-N\(_4\)) were measured with Kjeldahl method: soil samples boiled in 0.01 N H\(_2\)SO\(_4\) solution to get ammonium sulfate solution, followed by distillation and adding devarda alloy process which is adding excess base to the acid digestion mixture to convert N-N\(_4\)+ to NH\(_3\) followed by boiling and condensation of the NH\(_3\) gas in receiving solution and
titration of the excessive ammonia in the receiving solution by 0.01 HCl. Devarda Allow was added last step solution to get nitrate after distillation and titration. Organic nitrogen of plant tissue were oxidized in acid condition and mixed with catalyst (NH₄)₂SO₄ followed by distillation process with adding NaOH solution and titration of the excessive ammonia in the receiving solution by 0.01 H₂SO₄. ammonium ion content was determined as total nitrogen/nitrogen content in plant tissue [6]. Nitrogen uptake was calculated by the following equation = Plant dry weight (g) x percentage (%) nitrogen content on plant tissue.

2.3. Data analysis

The SAS 9.1 analytical software package was used for all statistical analyses. The results were analyzed in two-way ANOVA of SAS 9.1 to determine effects of various kind of fertilizers and rice varieties on nitrogen uptake and crop yields. Individual means were compared to the Duncan Multiple Range Test.

3. Results and Discussion

Based on Table 2, Carbon content of Neem Cake was higher (45.14%) compared to *Azollamicrophylla* (37.88%) and cow manure (25.36%). The highest total nitrogen content was found in Neem Cake (3.23%). Respectively the content of total nitrogen of *Azollamicrophylla* and cow manure were 2.14% and 1.45%. C/N ratio of Neem cake, *Azollamicrophylla* and Enriched Cow manure were (13.97; 17.70 and 17.48, respectively). Total phosphorus (P) and total potassium (K) content of Neem cake, *Azollamicrophylla* and Enriched Cow manure were respectively 0.26%; 1.32%; 1.04% and 1.00%; 0.35%; 0.30%. Organic fertilizer contain various nutrients, both macro and micro nutrients in large amount. Organic fertilizers were in terms of soil biology and soil physics so that organic fertilizers also good for soil conditioner.

Table 2. Chemical properties of organic fertilizers

| Parameters     | Neem Cake | *Azollamicrophylla* | Enriched Cow manure |
|----------------|-----------|---------------------|---------------------|
| Organic Carbon (%) | 45.14     | 37.88               | 25.36               |
| Ratio C:N       | 13.97     | 17.70               | 17.48               |
| Total N (%)     | 3.23      | 2.14                | 1.45                |
| Total P (%)     | 0.26      | 1.32                | 1.04                |
| Total K (%)     | 1         | 0.35                | 0.30                |

Table 3 showed that application of fertilizer and rice varieties did not influence the ammonium and nitrate content in soil. Individually, fertilizer treatments significantly influenced the ammonium content. Ammonium content of fertilizers treatments was ranged from 4.98-11.20 mg kg⁻¹ and the highest ammonium content was resulted from Neem Cake treatment (P1) 11.20 mg kg⁻¹ and the lowest was cow manure found in control treatment (4.98 mg kg⁻¹). Neemcake contain the highest N than Azolla and cow manure.
Table 3. Effect of fertilizer and varieties treatment on ammonium (NH$_4^+$) and nitrate (NO$_3^-$) content in soil

| Treatments          | N available (mg kg$^{-1}$) |          |          |
|---------------------|-----------------------------|----------|----------|
|                     | NH$_4^+$                    | NO$_3^-$ |
| Ciherang (V1)       | 9.78a                       | 2.99 a   |
| MenthikSusu (V2)    | 10.86a                      | 2.31 a   |
| Control (P0)        | 4.98 b                      | 2.20 ba  |
| Neem Cake (P1)      | 11.20 a                     | 1.75 b   |
| Azolla(P2)          | 8.8  b                      | 2.85 ba  |
| Cow Manure (P3)     | 8.5  b                      | 3.66 a   |
| Inorganic Fertilizers (P4) | 9.47 a b | 3.28 ba  |

Data followed by the same letter in the column are not significantly different at the $P<0.05$ level, according to Duncan’s test.

There were no significant differences in nitrate (NO$_3^-$) content due to both rice varieties and fertilizers treatments. Nitrate contents in soil were ranged from 1.75 mg kg$^{-1}$ to 3.66 mg kg$^{-1}$. Neem cake treatment resulted lowest nitrate (NO$_3^-$) content than other treatments (1.75 mg kg$^{-1}$).[7] reported that neemseed retarded the activity and growth of the bacteria responsible for nitrification and denitrification. Polifenol in Neem Cake prevented activity of bacterial in nitrification and denitrification[8]. The amount of ammonium was higher than nitrate. Anaerobic conditions NO$_3^-$ undergoes denitrification because a lack of oxygen forces microbes to use NO$_3^-$ as a terminal electron acceptor. In this case, it is likely nitrification reactions (oxidation of NH$_4^+$) are moving slowly, so NH$_4^+$ would likely be more available.

Table 3 represent the nitrogen concentration and related uptake by rice plants. The data reported show that there was significant different among fertilizer treatments. The highest N content was found in Neem cake fertilizer treatment and the lowest was in control treatment that was 0.89% and 0.45%, respectively. Leaf nitrogen concentration is one of the most important plant N variables that determine photosynthetic C fixation and plant productivity. High nitrogen concentration in leaf indicate that plants absorb nutrient effectively[9]. The lowest plant N content in control treatment was affected by no fertilizers added to the plots.

Table 4. Effect of fertilizer and varieties treatment on nitrogen concentration and nitrogen uptake in plant

| Treatments          | N content in plant (%) | N uptake in plant (mgplant$^{-1}$) |
|---------------------|------------------------|-----------------------------------|
| Ciherang (V1)       | 0.71 a                 | 23.34 b                           |
| MenthikSusu (V2)    | 0.69 a                 | 27.43 a                           |
| Control (P0)        | 0.45 e                 | 15.50 c                           |
| Neem Cake (P1)      | 0.89 a                 | 37.83 a                           |
| Azolla(P2)          | 0.61 d                 | 16.66 c                           |
| Cow Manure (P3)     | 0.82 b                 | 34.50 a                           |
| Inorganic Fertilizers (P4) | 0.73 c     | 21.33 b                           |

Data followed by the same letter in the column are not significantly different at the $P<0.05$ level, according to Duncan’s test.
There was significant different between both rice varieties and fertilizer treatments due to nitrogen uptake in plant. Menthik susu varieties showed higher N uptake in plant (27.43%) than Ciherang (23.34%). According to the weight of dry matter local varieties (Menthik Susu) more than Ciherang. Therefore, the uptake of nitrogen is almost similar to that of dry matter [10]. Plant Neem cake treatment showed highest nutrient uptake (37.83 mg plant\(^{-1}\)) and not significant different with cow manure treatment (34.50 mg plant\(^{-1}\)).

![Figure 1. Histogram of Dry Grain Harvest (DHG) yields (kg ha\(^{-1}\)).](image)

Based on figure 1. The range of DHG was from 2.3-4.2 kg ha\(^{-1}\). The highest result of DHG was showed by Menthik susu (V2) with P1 (Neem Cake) treatments (4.2 kg ha\(^{-1}\)). Individually Neem cake treatments resulted highest yield of DHG in both Menthik Susu and Ciherang. The histogram showed Menthik Susu resulted higher yield than Ciherang, except in control treatment. Neem cake served highest nitrate content than other treatment (Table 3) so high nitrogen source lead to high nitrogen uptake in plant (Table 4). Plant residues with high N content and narrow C/N ratio are reported to improve crop yield mainly by supplementing N supplies to plant [11].

4. Conclusion
The application of fertilizers and rice varieties were not significantly affected N available and N uptake. Hence, higher Nitrogen uptake and grain yield were showed by Neem cake and var. Menthik susu. With considerably high Nitrogen uptake and rice grain yield, combination between Neem cake and rice var. Menthik Susu have a prospect as a solution to maintain soil quality and yield in organic farming.

References
[1] Kementrian Pertanian Republik Indonesia 2015 Rencana Strategis Kementrian Pertanian Tahun 2015-2019 (Jakarta: Biro Perencanaan Sekretariat Jenderal)
[2] Dobermann A, Witt Cand Dawe D 2004 Intl. Rice Res. Inst. pp 410
[3] Curley EM, O’Flynn MG and Macdonnel KP 2009 J. Agron 8 (3): 107–112
[4] Whitworth RL, KMBechazand BW Dunn 2007 Proc of the 4\(^{th}\) Temperate Rice Conference, June 25-28 2007 pp 88-89
[5] Cavigiolo S, Bocchi S, Gallina P M and Lupotto E 2007 Proc of the 4\(^{th}\) Nitrogen fertilization in rice, June 25-28 2007, 292
[6] Balittanah 2009 Analisis Kimia Tanah, Tanaman, Air, dan Pupuk (Bogor: Balai Penelitian Tanah)
[7] Lokanadhan, SubbalakshmiP, Muthukrishnan and SJeyarama2012\textit{Biopest}5: 72-76
[8] KartikawatiR, SusilawatiH L, ArianiMand Setyanto P2011TeknologiMitigasiGas RumahKaca (GRK) (BuletinSinartani), 21-27 September 2011 No.3423
[9] YuanAn, Shiqiang W, Xuhui Z, Afzal, A.S, Linda, LWand YiqiL2005\textit{Global Change Biology}11:1733 – 1744
[10] IslamM A, Islam MRand Sarker ABS2008\textit{J Agric Rural Dev}6(1&2): 7-12
[11] AzamF, Ashraf M, Lodhi A and Sajjad MI1991\textit{Biol. Fertil. Soils}11:57-61