**Paddy husk compost addition for improving nitrogen availability**

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**ABSTRACT**

Mature compost with good agronomic properties can be used to control nitrogen loss from soil. Soil incubation and leaching experiments were conducted to determine the effects of paddy husk compost addition on controlling ammonium and nitrate losses from Bekenu Series soil. Retention of soil exchangeable ammonium and available nitrate were significantly improved in soil amended with paddy husk compost treatments compared with urea alone thus, reducing leaching of these ions. At 30 days of the leaching experiment, ammonium and nitrate losses were highest in urea without paddy husk compost addition compared with co-application of urea and paddy husk compost because the treatment significantly improved retention of soil exchangeable ammonium and available nitrate. Urea can be co-applied with paddy husk compost to improve release of ammonium and nitrate and to retain nitrogen availability.

**Key words:** Leaching, Mineral nitrogen, Nitrogen retention, Paddy husk, Soil amendments.

**INTRODUCTION**

Nitrogen (N) fertilizers use in agricultural systems is an essential facet of modern agriculture which currently feeds 7 billions people in the world (Erisman et al., 2008). Intensification of agricultural production and increasing use of N fertilizers is the key to meet global yield demands (Zhou et al., 2013; Choudhary et al., 2013). However, high production cropping systems are always associated with substantial hydrological and gaseous N losses (Bai et al., 2017). Leaching of NO₃⁻ is one of the most important N loss pathways because NO₃⁻ is extremely mobile (Choudhary and Suri, 2009). The challenge remains to link crop production efficiency with environmental quality (Paul et al., 2014; Kumar et al., 2016). One of the better methods of reducing losses of mineral N is through the use of compost (Paul et al., 2016; Choudhary and Suri, 2018). Rates of N mineralization and subsequent NO₃⁻ leaching can be minimized by the incorporation of compost into soils. The combination of inorganic fertilizers and organic amendment such as compost is recognized as one of the methods to reduce the need for inorganic fertilizers and minimize soil degradation (Choudhary et al., 2008; 2010). In this study, the addition of paddy husk compost as soils organic amendment is considered as an important alternative method in sustainable wastes management. Previous studies have dealt with environmental and economic benefits of compost used in agriculture (Alburquerque et al., 2007; Paul et al., 2016). However, information on the fate of mineral N following specifically on the addition of paddy husk compost to soil remains scarce globally. Thus, the objective of this study was to determine the effects of paddy husk compost in controlling the ammonium (NH₄⁺) and NO₃⁻ release in Bekenu Series soil (Typic Paleudults).

**MATERIALS AND METHODS**

**Physico-chemical characteristics of paddy husk compost:** The procedures of compost production and selected physico-chemical properties of the paddy husk compost (Table 1) were adapted from our previous paper (Latifah et al., 2015). The chemical properties of the humic acids extracted from the paddy husk compost are given in Table 2.

**Selected physical and chemical properties of Bekenu series soil (Typic Paleudults):** The soil used in this study was Bekenu Series (Typic Paleudults) which was collected at 0–20 cm depth from an uncultivated area at Universiti Putra Malaysia Bintulu Campus Sarawak, Malaysia (latitude 3°30\'N, longitude 113°09\'E). The soil was air dried and ground to pass a 2 mm sieve for initial characterization, incubation, and leaching experiments. The pH of the soil was determined in a ratio of 1:2 (soil: distilled water suspension). The soil total C, N, and organic matter were determined using Leco CHNS Analyzer (LECO Truspec Micro Elemental Analyzer CHNS, New York). Soil available P was extracted using the double acid method followed by blue method (Tan, 2005). Exchangeable cations were extracted using the leaching method (Tan, 2005) and their contents were determined using Atomic Absorption Spectrophotometry (Analyst 800, Perkin Elmer, Norwalk, USA). Soil CEC was determined using the leaching method (Tan, 2005). The method of Keeney and Nelson (1982) was

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used to extract exchangeable NH$_4^+$ and available NO$_3^-$ after which their contents were determined using steam distillation. The selected chemical properties of the soil are summarized in Table 3.

Table 1: Selected physico-chemical properties of paddy husk compost.

| Property                  | Value obtained (Mean ± S.E.) |
|---------------------------|-------------------------------|
| pH value                  | 7.9 (± 0.03)                  |
| CEC (mol kg$^{-1}$)       | 176 (± 3.17)                  |
| Humic acid (%)            | 5.7 (± 0.03)                  |
| EC (ds m$^{-1}$)          | 1.2 (± 0.02)                  |
| Total carbon (%)          | 28.2 (± 0.52)                 |
| Organic matter (%)        | 47 (± 0.55)                   |
| Total nitrogen (%)        | 1.6 (± 0.03)                  |
| C/N ratio                 | 17                            |
| Ammonium (mg kg$^{-1}$)   | 362 (± 2.92)                  |
| Nitrate (mg kg$^{-1}$)    | 172 (± 1.85)                  |
| Total phosphorus (mg kg$^{-1}$) | 1097 (± 0.88)         |
| Calcium (mg kg$^{-1}$)    | 15.080 (± 0.88)               |
| Magnesium (mg kg$^{-1}$)  | 15.350 (± 1.45)               |
| Potassium (mg kg$^{-1}$)  | 27.720 (± 0.88)               |
| Iron (mg kg$^{-1}$)       | 3.6 (± 0.14)                  |
| Zinc (mg kg$^{-1}$)       | 11.2 (± 0.17)                 |
| Copper (mg kg$^{-1}$)     | 2.4 (± 0.11)                  |
| Manganese (mg kg$^{-1}$)  | 2.1 (± 0.12)                  |
| Ash content (%)           | 6.4 (± 0.29)                  |
| Moisture content (%)      | 44 (± 0.71)                   |

Values were obtained from our previous study on co-composting paddy husk and chicken manure (Latifah et al., 2015). Values in parenthesis represent standard error of the mean. Carbon to N ratio was calculated by dividing the percentage of C with the percentage of N.

Table 2: Selected chemical properties of humic acid extracted from paddy husk compost.

| Property                  | Value obtained (Mean ± S.E.) | Tan (2003) |
|---------------------------|-------------------------------|------------|
| $E_r/E_i$                 | 7.78 (± 0.03)                 | 7 – 8      |
| Phenolic (mol kg$^{-1}$)  | 350 (± 5.54)                  | 240 – 540  |
| Carboxyl (mol kg$^{-1}$)  | 400 (± 10.68)                 | 150 – 440  |
| Total acidity (mol kg$^{-1}$) | 750 (± 5.03)                  | 500 – 700  |

Values in parenthesis represent standard error of the mean.

Table 3: Selected chemical properties of Bekenu series soil (Typic Paleudults).

| Property                  | Value obtained (Mean ± S.E.) | Standard data range |
|---------------------------|-------------------------------|---------------------|
| pH$_{water}$              | 4.66 ± 0.10                   | 4.6                 |
| CEC (mol kg$^{-1}$)       | 7.43 ± 0.15                   | 8.0 – 24            |
| Exchangeable calcium (mol kg$^{-1}$) | 1.41 ± 0.05 | 0.01                |
| Exchangeable magnesium (mol kg$^{-1}$) | 1.53 ± 0.05 | 0.21                |
| Exchangeable potassium (mol kg$^{-1}$) | 0.60 ± 0.02 | 0.19                |
| Total Nitrogen (%)        | 0.15 ± 0.01                   | 0.04 – 0.17         |
| Organic matter (%)        | 2.06 ± 0.10                   | nd                  |
| Total carbon (%)          | 1.20 ± 0.60                   | 0.57 – 2.51         |
| Available phosphorus (mg kg$^{-1}$) | 4.16 ± 0.13 | nd                  |
| Exchangeable ammonium (mg kg$^{-1}$) | 19.85 ± 0.68 | nd                  |
| Available nitrate (mg kg$^{-1}$) | 5.16 ± 0.09 | nd                  |

S.E. is standard error. Standard data range reported by Paramanathan (2000). CEC is cation exchange capacity. nd is not determined.

Soil incubation and leaching experiments: A soil incubation experiment was carried out for 90 days in the Soil Science Laboratory of Universiti Putra Malaysia Bintulu Sarawak Campus, Malaysia. The treatments evaluated in this experiment were:

(i) Soil (no urea) ($T_0$)
(ii) Soil + 7.40 g urea without additives ($T_1$)
(iii) Soil + 7.40 g urea + 6 g paddy husk compost ($T_2$)
(iv) Soil + 5.55 g urea + 12 g paddy husk compost ($T_3$)
(v) Soil + 3.70 g urea + 18 g paddy husk compost ($T_4$)

The rates of the urea and compost used in this study were based on standard fertilizers’ recommendation for maize cultivation (MARDI, 1993). However, the amount of urea applied in $T_1$ and $T_2$ were reduced by 25 and 50% of the standard recommendation, whereby complemented by the addition of 10, and 15 t ha$^{-1}$ of paddy husk composts. The different rates of paddy husk compost used in this study were scale down from application of 5, 10, and 15 t ha$^{-1}$ in maize cultivation. The samples were incubated for 30, 60, and 90 days at 26 °C, respectively. Each treatment had 3 replications; that is, 15 samples for 30 days of incubation, 15 samples for 60 days of incubation, and 15 samples for 90 days of incubation (DAI). At 30, 60, and 90 DAI, the soil samples were air-dried and analyzed for pH, total N, NH$_4^+$, and NO$_3^-$ content.

The similar treatments evaluated in soil incubation were leached for 30 days. The mixture was filled in leaching tubes and leached with distilled water after which the leachates were collected at three days interval based on a five year rainfall. Afterwards, the leachates were analyzed for NH$_4^+$, NO$_3^-$ and pH. The soil samples at 30 days of the leaching experiment were analyzed for total N, exchangeable NH$_4^+$, and available NO$_3^-$. Experimental design and statistical analysis: The soil incubation experiment was a factorial experiment arranged in completely randomized design (CRD) with two factors, namely treatments and time of incubation in triplicates. Leaching experiment was arranged in CRD with three
Table 4: Effects of treatments and time on mean square of soil total nitrogen, exchangeable ammonium, available nitrate, and pH.

| SV               | DF | Total N | NO$_3^-$ | pH  | NH$_4^+$ |
|------------------|----|---------|-----------|-----|----------|
| Time             | 2  | 0.30*   | 9654.22*  | 941.37* | 0.02**  |
| Treatment        | 4  | 0.09*   | 177665.95*| 36740.82*| 13.24*  |
| Time vs Treatment| 8  | 0.004*  | 5142.38*  | 125.41* | 0.005*  |
| Error            | 30 |         |           |      |          |

SV is source of variance. DF is degree of freedom. *Significant difference at $P \leq 0.05$. ns= no significant.

RESULTS AND DISCUSSION

Soil total nitrogen and pH: At 30 DAI, T$_1$, T$_2$, T$_3$, and T$_4$ showed no significant effect on soil total N (Fig 1). However, higher soil total N was observed in the reduction of urea by 75 and 50% of standard recommendation with the addition of 10 and 15 t ha$^{-1}$ of paddy husk compost at 60 DAI. At 90 DAI, all treatments with paddy husk compost significantly increased soil total N compared with urea alone (T$_1$). The higher retention of soil total N in the soil with paddy husk compost compared with urea alone is due to slow release of N from compost because the fertilizing effect following paddy husk compost application lasts longer due to gradual release of nutrients (Smith and Collins, 2007). Therefore, with paddy husk compost, there is a better protection of N from being leached compared to soluble urea fertilizer only. The higher soil total N was partly due to the high organic matter (47%) of the paddy husk compost used in this study. This is because during mineralization, stable organic N of paddy husk composts is slowly but steadily released over time (Choudhary and Rahi, 2018). The high CEC of paddy husk compost (176 cmol$_c$ kg$^{-1}$) also enhanced soil total N of the soils with paddy husk compost particularly at 90 DAI.

Urea amended with paddy husk compost significantly increased soil pH compared with those of soil alone and urea without additives at 30, 60, and 90 DAI, respectively (Fig 2). The higher soil pH due to T$_1$, T$_3$, and T$_4$ was because soil pH increases as urea hydrolysis progresses. As urea hydrolyzes, NH$_4^+$, OH$^-$, and CO$_3^{2-}$ ions are released to increase soil pH (Adams and Martin, 1984). Adams and Martin (1984) also reasoned that mineralization of organic N occurs when soil pH ranges between 6.5 and 7.5, but the rate of mineralization decreases when soil pH is below 6.

Soil exchangeable ammonium and available nitrate: Urea with the addition of paddy husk compost significantly increased soil exchangeable NH$_4^+$ compared with urea without additives and soil alone at 30, 60, and 90 DAI (Fig 3). Higher soil total N in the treatments with paddy husk compost influenced the amount of NH$_4^+$ released than in the soil alone and soil with urea alone. As shown in Fig. 4, soil available NO$_3^-$ was significantly higher in all the mixtures at 30 and 60 DAI compared with urea without additives. At 90 DAI, higher soil available NO$_3^-$ was observed in T$_3$ and T$_4$ compared with T$_1$. These suggest that the paddy husk compost reduced leaching loss of NO$_3^-$ from the soil. Treatment$_2$ and T$_4$ were able to absorb soil exchangeable NH$_4^+$ because of the humic acids content (5.7%) of the compost used in these treatments (Table 1). The higher soil available NO$_3^-$ was partly due to the C/N ratio (17:1) of the paddy husk compost (Table 1). In the study of Xia et al. (2007), the concentrations of NO$_3^-$N in their first leachates were high but they decreased in the subsequent leachates for all compost amended media. The increase in soil pH (due to pH of the paddy husk compost) also contributed to the significant increase in available NO$_3^-$ at 30, 60, and 90 DAI.

![Figure 1:](image_url) Effects of treatments (T$_0$, T$_1$, T$_2$, T$_3$, and T$_4$) and periods of incubation (30, 60, and 90 days) on soil total N. Means with same letter are not significantly different by Tukey’s test at $P \leq 0.05$. Letters without prime represents 30 DAI, single prime superscript represents 60 DAI, and double prime superscript represents 90 DAI.
Fig 2: Effects of treatments (T0, T1, T2, T3, and T4) and periods of incubation (30, 60, and 90 days) on soil pH. Means with same letter are not significantly different by Tukey’s test at $P \leq 0.05$. Letters without prime represents 30 DAI, single prime superscript represents 60 DAI, and double prime superscript represents 90 DAI.

Fig 3: Effects of treatments (T0, T1, T2, T3, and T4) and periods of incubation (30, 60, and 90 days) on soil exchangeable ammonium. Means with same letter are not significantly different by Tukey’s test at $P \leq 0.05$. Letters without prime represents 30 DAI, single prime superscript represents 60 DAI, and double prime superscript represents 90 DAI.

Fig 4: Effects of treatments (T0, T1, T2, T3, and T4) and periods of incubation (30, 60, and 90 days) on soil available nitrate. Means with same letter are not significantly different by Tukey’s test at $P \leq 0.05$. Letters without prime represents 30 DAI, single prime superscript represents 60 DAI, and double prime superscript represents 90 DAI.
and T₄ at thirty days of soil leaching partly because the paddy husk compost served as a source of organic matter for N stabilization in the soil. This is because N is stored in soils in organic form, thus the quantity and nature of organic matter and its decomposition in the soil has effect on the long-term availability of N (Rahi and Choudhary, 2014; 2016).

**The pH of leachate:** The lower pH in T₁ compared with the treatments with paddy husk compost (Fig 7) explains the leaching loss of NH₄⁺ and NO₃⁻ as discussed previously in Fig 5 and 6. The formation of dissolved NH₄ could be the reason for the lower leachate pH in T₁. This is because H⁺ released from NH₄⁺ lowered pH of the leachate. The ability of T₃, T₄, and T₄ to maintain the pH of the leachates was due to the buffering capacity of paddy husk compost. In a related study, Choudhary and Suri (2009) stated that acidification processes can be balanced by maintaining or enhancing pH through regular use of soil organic amendment.

**Soil exchangeable ammonium, available nitrate, and total nitrogen:** At the end of the leaching experiment, urea with paddy husk compost showed significant effects on soil exchangeable NH₄⁺ and available NO₃⁻ compared with urea without additives (Fig 8). Soil exchangeable NH₄⁺ and available NO₃⁻ were lower in urea without additives because they were leached as discussed previously. The addition of paddy husk compost improved retention of soil exchangeable NH₄⁺ and available NO₃⁻ compared with urea without additives partly due to the ability of the paddy husk compost to increase water holding capacity of the soil (Choudhary and Rahi, 2018). Owing to this, leaching of NH₄⁺ and NO₃⁻ was reduced. This is because losses of N occur when soils have more incoming water than they can hold. The higher soil exchangeable NH₄⁺ and available NO₃⁻ retained under the treatments with paddy husk compost is also related to slow release of NH₄⁺ and NO₃⁻ from the compost (Choudhary and Suri, 2009; Dhillon et al., 2018). All treatments with additives showed higher concentrations of soil total N than
in urea alone suggesting that paddy husk compost ensured slow release of urea-N (Fig 9). The lower total N in urea alone compared with co-application of urea with paddy husk compost because N was loss due to leaching of NH$_4^+$ and NO$_3^-$. The findings of this study suggest that application of urea in soil can be properly managed if it is amended with paddy husk compost to improve the N availability.

CONCLUSION

Overall, the addition of paddy husk compost reduced the N loss (leaching of NH$_4^+$ and NO$_3^-$) by retaining soil exchangeable NH$_4^+$ and available NO$_3^-$. The findings of this study suggest that application of urea in soil can be properly managed if it is amended with paddy husk compost to improve the N availability.

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