

Full Length Research Paper

Effect of mixing urea with zeolite and sago waste water on nutrient use efficiency of maize (*Zea mays* L.)

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The efficiency of urea is poor due to the substantial amount of N lost to the atmosphere by ammonia volatilization. Thus, the objectives of this greenhouse study were to evaluate the effectiveness of mixing urea with zeolite and sago waste water on N, P and K uptake and their use efficiency in maize cultivation, and soil exchangeable ammonium, available nitrate, pH, exchangeable K, and available P contents. The treatments evaluated were: No fertilizer (T0), 2.02 g urea (T1), 2.02 g urea + 30 g zeolite + 7 L sago waste water (T2), 2.02 g urea + 40 g zeolite + 7 L sago waste water (T3), and 2.02 g urea + 7 L sago waste water (T4). Triple Super Phosphate (TSP) and Muriate of Potash (MOP) were used as sources of P and K for all the treatments except for T0. These fertilizers were applied twice that is 10 and 28 days after planting. Phosphorus and K requirements of the test crop were met by applying TSP and MOP (standard rate for the test crop) to plants of all the treatments except T0. The mixtures of sago waste water, and zeolite, with urea had significant effect on dry matter, N, P, K uptake and N, P, K use efficiency compared with urea without additives. These mixtures also significantly increased soil exchangeable ammonium, K, Ca, Mg, available P, and nitrate contents compared with urea without additives. Amending urea with sago waste water and peat soil water can reduce ammonia loss by encouraging formation of ammonium and nitrate over ammonia. Additionally, the mixtures ensure N, P, K uptake and their use efficiency while at the same time making soil ammonium, K, Ca, Mg, P, and nitrate available for plant use.

Key words: Urea, ammonia volatilization, zeolite, sago waste water, exchangeable ammonium, available nitrate, maize.

INTRODUCTION

Favourable economics of manufacturing, handling, storage and transportation have made urea a very competitive source of N fertilizer (John et al., 1999). However, the efficiency of urea is poor due to the substantial amount of N lost to the atmosphere by ammonia volatilization. Ammonia volatilization is a direct economic loss to the farmer whereby as much as 40 to 70% of some surface applied N fertilizers can be volatilized (Bouwman et al., 1997). Urea is converted to

ammonium ions following its application to the soil by enzyme urease (Stumpe et al., 1984). Broadcasting urea at the surface is a common practice in agriculture because of the ease of application and the low cost of urea (Bremner, 1995). When urea is surface-applied, the formation of NH_3 at the soil surface from urea hydrolysis may allow some NH_3 loss, and if urea is banded with the seed, some plant damage may occur because of NH_3 toxicity. The severity of both processes depends largely on the concentration of NH_3 formed (Bremner, 1995). As much as 70% of N fertilizers applied to the soil surface may be lost through NH_3 volatilization (Bouwman et al., 1997). Several approaches have been explored for reduction of the problems encountered in the use of urea

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fertilizer (Latifah et al., 2011a, b, c; Ahmed et al., 2010; Latifah et al., 2010). The mixtures of urea, triple superphosphate (TSP) and zeolite effectively reduced NH_3 volatilization and able to accumulate NH_4^+ in the 0 to 3 cm depth of soil.

Applying urea with TSP and zeolite offers a significant advantage over urea without additives by increasing the formation of NH_4^+ over NH_3 and retaining more NH_4^+ within the soil (Ahmed et al., 2006). In order to decrease the loss of N due to the NH_3 volatilization, zeolite can be used because of high specific surface areas and their rigid framework but the most commercially valuable and dynamic property of zeolite is its CEC (Ming and Dixon, 1986). The most common exchangeable cations found in natural zeolite molecules are Na, Ca, K, and Mg, many of which are desirable in numerous biological and industrial processes (Hashimoto et al., 1992). Additionally, the acid nature waste water from sago (pH 3.5) could also be exploited for ammonia loss from urea. NH_3 volatilization increase with higher soil pH because of the dissociation of NH_4^+ to NH_3 , thus increasing the potential for volatilization (Taufik et al., 2009; Ameera et al., 2009; Bernard et al., 2009; Rosliza et al., 2009a, b; Ahmed et al., 2010; Latifah et al., 2010; Zhengping et al., 1991). There is continuing need to improve the efficiency of N fertilizer use, to achieve more efficient production of food crops.

It is very well known that the deficiency of any other essential plant nutrient is bound to affect nitrogen use efficiency. A balanced fertilization of N along with P and K can largely increase the agronomic efficiency of fertilizer N (Shahrawat, 1989). Hence, the objectives of this greenhouse study were to evaluate the effectiveness of mixing urea with zeolite and sago waste water on N, P and K uptake and their use efficiency in maize cultivation, and soil exchangeable ammonium, available nitrate, pH, exchangeable K, and available P contents.

MATERIALS AND METHODS

Waste water from sago palm (*Metroxylon sago*) was collected from Song Ngeng Sago Industries Dalat, Mukah, Sarawak, Malaysia. The clinoptilolite zeolite used in this study was imported from Indonesia. The mineral soil used in this study was sampled in an undisturbed area of Universiti Putra Malaysia Bintulu Sarawak Campus, Malaysia using an auger. The soil taken at 0 to 15 cm depth was air dried and ground to pass 2.0 mm sieve for pot experiment (greenhouse). Soil texture was determined using the hydrometer method and its field capacity and bulk density determined by the method described by Tan (2005). The pH of the soil and zeolite were determined in a 1:2 soil:Distilled water suspension and KCl using a glass electrode (Peech, 1965). However, the pH of sago waste water was determined directly from filtered samples using a glass electrode. The soil total carbon was determined using the Loss-on-ignition method (Tan, 2005). Soil available P was extracted using the double acid method followed by blue method (Murphy and Riley, 1962). The Kjeldhal method was used to determine total N (Tan, 2005). Exchangeable cations were extracted using the leaching method (Cottenie, 1980) and their concentrations were afterwards determined using followed Atomic

leaching method followed by steam distillation (Tan, 2005). The CEC of clinoptilolite zeolite was determined using the CsCl method (Ming and Dixon, 1986). It must be noted that the CsCl method used is the most suitable method because the leaching method tends to underestimate CEC of zeolites because of trapping of ammonium ions in zeolites channels (Ming and Dixon, 1986).

The pot experiment was conducted in a greenhouse at the Universiti Putra Malaysia Bintulu Sarawak Campus, using completely randomized design with three replicates. The pots used were in a size of 22 x 28 cm and consisted of 10 kg soil (based on soil bulk density). Maize (*Zea mays* L.) of hybrid no. 5 was used as test crop. Requirement of N, P, and K were 60 kg N, 60 kg P_2O_5 and 40 kg K_2O (130 kg ha^{-1} urea: 130 kg ha^{-1} TSP: 67 kg ha^{-1} MOP). The fertilizer requirement was scaled down to per pot basis equivalent to 2.02 g of urea, 5 g of TSP and 5 g of MOP. The volume of water used for each pot was based on field capacity (70%). The treatments evaluated were: no fertilizer (T0), 2.02 g urea (T1), 2.02 g urea + 30 g zeolite + 7 L sago waste water (T2), 2.02 g urea + 40 g zeolite + 7 L sago waste water (T3), and 2.02 g urea + 7 L sago waste water (T4). Zeolite and first application of sago waste water of 3.5 L were applied before propagation, meanwhile another 3.5 L of sago waste water was applied 28 days after planting for all treatments except for T0 and T1. For T0 and T1, soils were moistened with 3.5 L of tap water. Triple Super Phosphate (TSP) and Muriate of Potash (MOP) were used as sources of P and K for all the treatments except for T0. These fertilizers were applied twice that is 10 and 28 days after planting. Phosphorus and K requirements of the test crop were met by applying TSP and MOP (standard rate for the test crop) to plants of all the treatments except T0.

At 56 days after planting, when the development of tassel had appeared, the maize was harvested and the tops of the plants were partitioned into stem and leaves. Roots were cleaned prior to oven drying. Leaves, stems and roots were oven dried at 60°C until constant weight was attained and their dry weight was determined. Each plant part was ground and analyzed for total N, P and K uptake and their use efficiency.

After harvested, soil samples were analyzed for pH, accumulation of NH_4^+ and NO_3^- , exchangeable cations and available P. Exchangeable Ca, Mg, and K were extracted with double acid method (Tan, 2005) and the extracts was analyzed as described previously. Exchangeable NH_4^+ and NO_3^- were extracted from the soil with the method of Keeney and Nelson (1982) and the amount was determined using steam distillation. Soil available P was extracted using the double acid method followed by blue method (Murphy and Riley, 1962).

Nitrogen, P and K use efficiency were determined by the formula (Pomarcés-García and Pratt, 1987);

$$\% \text{ Efficiency} = \frac{(A - B)}{C} \times 100$$

where A = Uptake with fertilizer, B = Uptake without fertilizer, C = Total amount of fertilizer that had been applied;

Uptake = Concentration x dry weight (g).

Nitrogen, P and K uptake in leaves, stem and roots were determined by multiplying the concentration with the dry weight of the plant parts. Analysis of variance (ANOVA) was used to test the effect of treatments, while means of treatments were compared using Duncan's Test. Statistical Analysis System (SAS Ver. 9.2) was used for the statistical analysis.

Absorption Spectrometry (AAS). Soil CEC was determined by the

Table 1. Selected physico-chemical properties of Bekenu series.

| Property | Value obtained | Standard data range* |
|---|----------------|----------------------|
| pH (water) | 4.11 | 4.6 – 4.9 |
| pH (KCl) | 3.86 | 3.8 – 4.0 |
| CEC (cmol _c kg ⁻¹) | 7.33 | 3.86 – 8.46 |
| Texture | SCL | SCL |
| Bulk density (g cm ⁻³) | 1.51 | nd |
| Organic matter (%) | 2.28 | nd |
| Available P (mg kg ⁻¹) | 2.39 | nd |
| Total Nitrogen (%) | 0.15 | 0.04 – 0.17 |
| Organic carbon (%) | 0.57 | 0.57 – 2.51 |
| Exchangeable Ca (mg kg ⁻¹) | 2.05 | 0.05 – 0.19 |
| Exchangeable Mg (mg kg ⁻¹) | 0.18 | 0.07 – 0.21 |
| Exchangeable K (mg kg ⁻¹) | 0.16 | 0.05 – 0.19 |

*Subject to the soil development, standard data range by Paramanathan (2000).

Table 2. Selected chemical properties of zeolite, sago waste water and urea.

| Property | Zeolite | Sago waste water | Urea |
|---|---------|------------------|------|
| pHw | 6.52 | 3.87 | 8.00 |
| pH (KCl) | 5.38 | nd | nd |
| CEC (cmol _c kg ⁻¹) | 100.33 | nd | nd |
| Total Nitrogen (%) | nd | 0.18 | nd |
| Exchangeable Ca (mg kg ⁻¹) | 20.19 | 0.21 | nd |
| Exchangeable Mg (mg kg ⁻¹) | 31.50 | 0.17 | nd |
| Exchangeable K (mg kg ⁻¹) | 28.16 | 0.19 | nd |

Table 3. Effect of treatments on ammonium and nitrate at 56 DAP.

| Trt | NH ₄ ⁺ N (ppm) | NO ₃ ⁻ N (ppm) |
|-----|--------------------------------------|--------------------------------------|
| T0 | 18.47 ^e | 3.67 ^d |
| T1 | 23.40 ^d | 5.34 ^c |
| T2 | 41.06 ^b | 7.32 ^a |
| T3 | 58.69 ^a | 7.80 ^a |
| T4 | 36.61 ^c | 6.16 ^b |

Means with the same letter within column are not significantly different by Duncan's test at P≤0.05.

RESULTS AND DISCUSSION

The selected physical and chemical properties of Bekenu Series are summarized in Table 1. The aforementioned properties were comparable with those reported by Paramanathan (2000) except for exchangeable Ca, which was relatively high probably because of liming. The pH of the sago waste water and zeolite were acidic while was high as well as its exchangeable Ca, Mg and K contents. All the mixtures had significant accumulation of soil exchangeable NH₄⁺ and available NO₃⁻ at 56 days

after planting compared with urea alone (Table 3). The retardation of nitrification in soil by the application of urea mixing with zeolite and sago waste water (T2, T3, T4) results in an accumulation of NH₄⁺ and enhance the pH of urea was basic (Table 2). The CEC of zeolite increasing incorporation of NH₄⁺ in the organic fraction (Kissel, 1988). Available NO₃⁻ was significantly high for T2, T3 and T4 compared to T1. Less NO₃⁻ formed (T1) is correlated to amount of NO₃⁻ N leached. With the exception of pH, all the mixtures significantly

Table 4. Effect of treatments on selected soil chemical properties at 56 DAP.

| Treatment | Ca (ppm) | Mg (ppm) | K (ppm) | P (ppm) | pH (water) |
|-----------|-------------------|-------------------|-------------------|-------------------|--------------------|
| T0 | 1.28 ^d | 1.26 ^d | 1.28 ^d | 0.28 ^d | 4.58 ^a |
| T1 | 2.32 ^c | 2.36 ^c | 2.63 ^c | 0.46 ^c | 3.94 ^{ab} |
| T2 | 3.07 ^b | 3.30 ^b | 3.16 ^b | 0.89 ^b | 3.97 ^{ab} |
| T3 | 4.05 ^a | 5.19 ^a | 5.07 ^a | 1.71 ^a | 4.03 ^{ab} |
| T4 | 2.89 ^d | 3.08 ^d | 3.07 ^d | 0.56 ^c | 3.88 ^d |

Means with the same letter are not significantly different by Duncan's test at $P \leq 0.05$

Table 5. Effect of treatments on dry weight of maize Plant at 56 DAP.

| Treatment | Stem | Leaves | Roots | Total |
|-----------|--------------------------|-------------------|-------------------|---------------------|
| | (g plant ⁻¹) | | | |
| T0 | 5.37 ^c | 4.23 ^c | 3.14 ^c | 12.74 ^d |
| T1 | 5.71 ^c | 6.00 ^b | 3.18 ^c | 14.89 ^{cd} |
| T2 | 6.49 ^{bc} | 6.40 ^b | 4.23 ^b | 17.12 ^{bc} |
| T3 | 8.23 ^a | 6.84 ^b | 6.70 ^a | 23.14 ^a |
| T4 | 7.51 ^{ad} | 8.21 ^a | 4.68 ^d | 19.03 ^b |

Means with the same letter within column are not significantly different by Duncan's test at $P \leq 0.05$.

Table 6. Effect of treatments on N, P, and K uptake of maize plant at 56 DAP.

| Trt | N | P | K |
|---------------|---------------------------|---------------------|--------------------|
| | (mg plant ⁻¹) | | |
| Stems | | | |
| T0 | 28.59 ^c | 11.27 ^d | 11.40 ^c |
| T1 | 32.84 ^{bc} | 12.29 ^{cd} | 22.24 ^b |
| T2 | 38.45 ^{ab} | 14.26 ^b | 22.76 ^b |
| T3 | 43.14 ^a | 15.96 ^a | 33.64 ^a |
| T4 | 36.84 ^b | 13.25 ^{bc} | 22.83 ^b |
| Leaves | | | |
| T0 | 43.03 ^e | 1.82 ^e | 9.11 ^d |
| T1 | 60.92 ^d | 4.31 ^c | 11.75 ^c |
| T2 | 67.49 ^c | 5.00 ^b | 22.68 ^b |
| T3 | 75.99 ^a | 6.07 ^a | 33.71 ^a |
| T4 | 73.18 ^b | 3.08 ^d | 22.37 ^b |
| Roots | | | |
| T0 | 12.44 ^d | 1.76 ^d | 12.43 ^e |
| T1 | 22.94 ^c | 3.93 ^b | 17.79 ^d |
| T2 | 23.19 ^{bc} | 5.37 ^b | 28.85 ^b |
| T3 | 28.07 ^a | 9.19 ^a | 39.93 ^a |
| T4 | 24.37 ^b | 3.19 ^c | 23.37 ^c |

Means with the same letter within column are not significantly different by Duncan's test at $P \leq 0.05$.

increased soil exchangeable Ca, Mg, K and available P compared with urea alone (Table 4). In related study (Ahmed et al., 2007), soil pH in laboratory incubation

experiment showed no significant effect regardless of treatment. The high CEC (100.33 cmol_c kg⁻¹) of zeolites in T2 and T3 contribute to accumulation of cations such as

Table 7. Effect of treatments on N, P, and K use efficiency in stem, leaves, and roots of maize at 56 DAP.

| Treatment | Stem | Leaves | Roots | Total |
|-----------|-------------------|-------------------|-------------------|--------------------|
| | | N (%) | | |
| T0 | nd | nd | nd | nd |
| T1 | 0.24 ^d | 1.26 ^c | 0.37 ^c | 1.87 ^d |
| T2 | 1.68 ^b | 5.11 ^a | 3.16 ^b | 9.77 ^b |
| T3 | 2.49 ^a | 5.19 ^a | 5.07 ^a | 12.75 ^a |
| T4 | 1.14 ^c | 3.08 ^b | 3.07 ^b | 7.29 ^c |
| | | P (%) | | |
| T0 | nd | nd | nd | nd |
| T1 | 0.32 ^c | 0.31 ^d | 0.40 ^c | 1.03 ^d |
| T2 | 2.07 ^b | 3.21 ^b | 1.91 ^b | 7.19 ^b |
| T3 | 3.05 ^a | 4.00 ^a | 2.64 ^a | 9.69 ^a |
| T4 | 1.89 ^b | 2.16 ^c | 0.50 ^c | 4.55 ^c |
| | | K (%) | | |
| T0 | nd | nd | nd | nd |
| T1 | 2.17 ^b | 1.17 ^c | 1.75 ^b | 5.09 ^c |
| T2 | 2.95 ^a | 1.65 ^d | 2.68 ^d | 7.28 ^d |
| T3 | 3.01 ^a | 2.49 ^a | 3.71 ^a | 9.21 ^a |
| T4 | 2.71 ^a | 1.14 ^c | 2.37 ^d | 6.22 ^{bc} |

Means with the same letter within column are not significantly different by Duncan's test at $P \leq 0.05$.

Ca, Mg and K (Mackdown and Tucker, 1985) in this study.

Dry weight of stem, leaves and roots for T3 was significantly higher than that of T1, T2 and T4 (Table 5). Higher amounts of zeolite mixed with urea and sago waste water (T3) had the best effect on the dry weight of the test crop. A similar result was obtained whereby urea with the highest amount additives significantly increased the dry weight of stem and leaf of Putra J-56 maize variety (Ahmed et al., 2007). A reflection of the effectiveness of the mixtures in reducing ammonia loss while improving urea-N use is demonstrated in Tables 6 and 7. All the mixtures significantly improved N uptake and use efficiency in all parts of the test crop compared with that of urea alone. This finding contradicted that of Ahmed et al. (2007) whereas only the treatments with the highest amounts of TSP and zeolite had significant effect on the increasing of urea-N uptake in the leaf of the test crop. The efficient use of urea-N in this study suggest that mixtures of sago waste water and zeolite can reduce ammonia loss by encouraging formation of ammonium and nitrate over ammonia. Similar observation was not glaring for P and K as the results were inconsistent.

Conclusion

The application of urea mixing with zeolite, and sago waste water is considered as amendments that could mitigate losses or reduce the NH_3 volatilization losses

from surface-applied urea as agronomic efficiency improves, economic and environment also benefit. Additionally, the mixtures ensure N, P, K uptake and their use efficiency while at the same time making soil ammonium, K, Ca, Mg, P, and nitrate available for plant use.

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