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Full Length Research Paper

Effect of amending urea with humic acids and acid sulphate on biomass production of Masmadu (*Zea mays* L.) and selected soil chemical properties

M. Y. Mohd Taufik[1], O. H. Ahmed[1]* and A. M. Nik Muhamad[2]

[1]Department of Crop Science, Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus, 97008 Bintulu, Sarawak, Malaysia.
[2]Department of Forest Management, Faculty of Forestry, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia.

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Excessive use of fertilizers especially nitrogenous fertilizers with low management in relation to food safety and environmental pollution has in recent times become a subject of concern. This greenhouse study compared the effect of three different urea-humic acid-acid sulphate soil mixtures on maize biomass production, soil pH, ammonium and nitrate contents, and urea use efficiency compared with urea-N without additives (urea alone). Humic acid (HA), acid sulfate soil and soil used in the greenhouse study were analyzed for selected soil physio-chemical properties. The fertilizer mixtures and ammonia loss determination were carried out using standard methods. The treatments were evaluated in a completely randomized block design with 3 replications. The data obtained at the end of the study on biomass production, soil pH, exchangeable ammonium and available nitrate were analyzed using analysis of variance and the means were compared using Duncan's test using statistical analysis systerm (SAS) version 9.2. The soil used to test treatments was a sandy clay loam Typic Tualemkuts (Nyalau Series). Urea amended with different levels of HA alone significantly improved soil exchangeable ammonium compared to urea alone. All the mixtures significantly improved soil pH compared with urea alone. However, all the mixtures did not significantly affect biomass production and content of available nitrate compared with urea alone. Amending urea with HA and acid sulphate soil did not significantly affect biomass production of Masmadu (test crop) but it significantly improved soil pH and retention of exchangeable ammonium.

Key words: Humic acid, acid sulphate soil, urea, ammonium, nitrate, *Zea mays,* biomass production.

INTRODUCTION

Excessive use of fertilizers with low management to meet crop requirement has become a subject to the food safety regulations and environmental pollution (FAO, 2006). The application of urea fertilizers in agriculture as one of the cheapest source of N fertilizers as an example can contribute to many environmental problems such as ammonia volatilization (Gupta, 2003).

Ammonia loss is one major environmental problem due to surface application of urea in agriculture (Preasertsak et al., 2001; Cai et al., 2002). Ammonia loss from urea is attributed to the rapid hydrolysis and dissolution of urea-N which is convened by soil and microclimate factors such as pH, cation exchange capacity (CEC), moisture and temperature (Havlin et al., 2005; Nelson, 1982; Al-Khaini et al., 1991). The amount of urea-N loss through volatilization ranges from 10 to 60% of the total N applied (Ahmed et al., 2006). The growing awareness about the polluting effect of excessive use of N fertilizers on the environment calls for improvement of urea-N use

*Corresponding author. E-mail: osman60@hotmail.com.

Abbreviations: HA, Humic acid; **SAS,** statistical analysis systerm; **CEC,** cation exchange capacity; **DAP,** days after planting; **DNMRT,** Duncan's new multiple range test; **ASS,** acid sulfate soils.

efficiency in agriculture. An approach of mixing urea with acidic materials such as acidic sulphate and phosphoric acids to control microsite pH can reduce the effect of NH_3 volatilization (Ahmad et al., 2006; Siva et al., 1999; Fan et al., 1993) but the high cost of amendments of this material prohibits their use.

The application of natural resources such as acid sulphate soil and humic acid (HA) which are readily available will help to improve urea-N use efficiency if urea is mixed with HA and acid sulphate soil (Latifah et al., 2011a, b, c; Ahmed et al., 2010, 2006). With the low pH of acid sulphate soil (usually less than 3.5) and HA from peat, a paradigm approach could be the use of little amount of this soil to amend urea before soil application. Besides controlling NH_3 loss (Ahmed et al., 2010; Latifah et al., 2010), this mixture can also reduce seedling damage from sulphate application (Bremner and Dougles, 1971) and increase the stock of label carbon, promoting nutrient plant growth and increasing nutrient uptake through the application of HA and acid sulphate soil (Leite et al., 2007).

The objective of this study was to investigate the effect of HA and acid sulphate soil mixtures on soil pH, exchangeable NH_4^+ and NO_3^-, and dry matter production of maize (*Zea mays*) on Nyalau Series (coarse loamy, siliceous, isohyperthermic, red-yellow to yellow Tipik Tualemkuts) (MARDI, 1990).

MATERIALS AND METHODS

The greenhouse study conducted to test the selected urea-N fertilizer mixtures was carried out in a completely randomized block design with 3 replications. The treatment evaluated were: 7.28 g urea (T_1), 7.28 g urea + 2.72 g HA +2.72 g acid sulfate soils (ASS) (T_2), 7.28 g urea + 2.72 g HA (T_3), 7.28 g urea + 3.60 g HA (T_4), and control (soil without any treatments) (T_0). The amount of urea applied in each treatment was based on the fertilizer requirement for *Zea mays* L. (Masmadu variety) per 3 plants and additional TSP and KCl as supplements were added to all treatments except control. The fertilizer requirement for Masmadu was 130.44 kg ha^{-1}; 130.44 kg ha^{-1} TSP and 66.67 kg ha^{-1} KCl (MARDI, 1990).

The fertilizers were surface applied ten days after planting (DAP) and 28^{th} DAP. Three out of five seedlings were maintained for observation before first fertilization throughout the study (60 DAP) in a pot (26 cm in diameter × 22 cm height). An 11 kg of Nyalau Series were applied based on the soil bulk density with 60 to 70% field capacity.

Prior to the greenhouse study, the fertilizer mixtures were prepared based on the method described by Ahmed et al. (2006) and Susilawati et al. (2008) with some modification where the materials were weighed separately based on the treatments before mixing them in a plastic vial by using a reciprocal mechanical shaker (200 rpm).

The HA was isolated from a tropical peat soil by the method described by Susilawati et al. (2008) with 4 h extraction and fractionation periods. The oven dried yield of HA was expressed as percentage (%) of the weight of soil used. Functional group analysis was conducted by the method described by Inbar et al. (1990).

The level of humification of HA was determined by E_4/E_6 method using spectroscopy (Stevenson, 1994). The model of the spectrometer used was Lambda 25 UV/VIS (Shelton, CT, USA).

The ASS was collected from Kuching, Sarawak (Telaga Air mangrove and Rempagi), Malaysia at 0 to 15 cm depth. The soil was air dried, meshed and sieved to pass a 2 mm sieve before it was characterized for pH (Brady and Weil, 2002), CEC by leaching with 1 N ammonium acetate (adjusted to pH 7) followed with steam distillation technique (Tan, 2005), total N by the Micro-kjedhal method (Tan, 2005), exchangeable cations (K, Ca, Mg, Na) by atomic absorption spectrophotometry (A Analyst 800, Perkin Elmer Instruments, Norwalk, CT) (Tan, 2005), and inorganic N (NO_3 and NH_4) (Keeney and Nelson, 1982). Both HA and ASS were meshed again to pass sieve less than 1 mm after which they were used to mix urea.

At tasseling stage (60 DAP), the plants were harvested and partitioned into leaf and stem. The remaining roots in the soil were collected by washing the soil from the roots using tap water. The plant parts were oven dried at 60°C to constant weight and weighed using a digital balance. Prior to harvesting, soil samples were taken from the pots and analyzed for pH, exchangeable NH_4^+, available NO_3^- using standard method.

Analysis of variance was used to test for treatments effects and means were compared using Duncan's new multiple range test (DNMRT) (SAS, 2007). The Statistical Analysis System software version 9.2 was used for the statistical analysis.

RESULTS AND DISCUSSION

The selected chemical properties of the soil (Table 1) were typical of Nyalau Series and were consistent with those reported by Paramananthan (2000). pH and CEC of the ASS were similar to those reported by Shamsuddin (2006) who also give the properties of tropical ASS. The carbon, phenolic, carboxylic and total acidity of HA were comparable with those reported by Schnitzer (1977) and Tan (2003).

The dry weight of roots, stem, and leaves of the test crop were statistical not different regardless of treatment (Table 2). This was because the vegetative growth may have been affected by the temporary acidic condition when the treatments (T_2, T_3, and T_4) were applied before the urea hydrolysed.

All the mixtures (T_2, T_3, and T_4) as shown in Table 3 significantly increased soil pH compared with the treatment of urea (T_1) at the end of 60 DAP. The decrease in soil pH under T_0 compared with the initial soil pH before planting was due to the production of hydrogen ions which might have dissociated from organic acids in the root cells when N was consumed (Havlin et al., 2005; Maiti and Wische-Ebeling, 1998). The hydrogen ions might have also been produced from nitrification and ammonification of soil organic N (Bolan and Hedley, 2003; Tang and Renzel, 2003). Increase in soil pH under T_2, T_3, and T_4 could be attributed to consumption of hydrogen ions during urea hydrolysis.

The soil exchangeable NH_4^+ and available NO_3^- accumulation at the end of the study are presented in Table 4. The significant increase in exchangeable NH_4^+ ions upon application of T_3 and T_4 compared to T_1 could be associated with NH_4^+ ions retention by HA during urea hydrolysis. A similar finding has been reported by Ahmed et al. (2008). On the other hand, T_3 and T_4 could not

Table 1. Selected chemical and physical properties of HA, ASS, and soil (Nyalau Series).

Property	HA	ASS	Soil
pH (water)	nd	3.45	4.85
pH (1 M KCl)	nd	nd	3.65
Total organic carbon (%)	55.59	nd	nd
CEC (cmol kg^{-1})	[a]	40.50	21.25
Carboxylic group (cmol kg^{-1})	300	nd	nd
Phenolic group (cmol kg^{-1})	220	nd	nd
Total acidity[a] (cmol kg^{-1})	520	nd	nd
Total N	nd	nd	0.413
Exchangeable K (cmol kg^{-1})	nd	nd	0.802
Exchangeable Mg (cmol kg^{-1})	nd	nd	0.018
Exchangeable Ca (cmol kg^{-1})	nd	nd	Trace
Exchangeable Na (cmol kg^{-1})	nd	nd	0.028
Exchangeable NH_4^+	nd	nd	0.154
Available NO_3^-	nd	nd	0.124
Field capacity (%)	nd	nd	75.57
Texture	nd	nd	SCL

CEC, Cation exchange capacity; SCL, sandy clay loam; nd, not determined; [a]CEC of humic acid = total acidity.

Table 2. Dry weight of leaves, stem, and roots of Masmadu at 60 DAP (g $plant^{-1}$).

Treatment	Leaves	Stem	Root	Total
T_0	2.12^a	2.35^a	1.77^a	5.83^a
T_1	2.20^a	1.80^a	0.87^a	5.28^a
T_2	1.91^a	2.00^a	0.71^a	5.25^a
T_3	1.99^a	1.66^a	1.43^a	5.08^a
T_4	1.69^a	1.87^a	0.68^a	5.07^a

Different alphabets indicate significant difference between treatments by Duncan's New Multiple range Test (DNMRT) at $p \leq 0.05$.

Table 3. Effect of treatments on soil pH after 60 DAP.

Treatment	pH_{water}	$pH_{acid (KCl)}$
T_0	3.93^e	3.41^d
T_1	4.65^d	4.02^c
T_2	5.47^a	4.90^a
T_3	4.82^c	4.23^b
T_4	5.27^b	4.78^a

Different alphabets indicate significant difference between treatments by Duncan's New Multiple range Test (DNMRT) at $p \leq 0.05$.

significantly improve available NO_3^- compared to T_1 because these treatments ensured formation of exchangeable NH_4^+ ions over available NO_3^-. The similarity in the soil chemical properties (Table 4) may also explain insignificant difference in the maize dry matter production regardless of treatment.

CONCLUSION AND RECOMMENDATION

Amending urea with HA and acid sulphate soil did not significantly affect biomass production of Masmadu (test crop) but it significantly improved soil pH and retention of exchangeable ammonium.

Table 4. Effect of treatments on exchangeable ammonium and nitrate accumulation after 60 DAP.

Treatment	Available NO_3^- (mg kg^{-1})	Exchangeable NH_4^+ (mg kg^{-1})
T_0	245.18^a	280.20^c
T_1	373.60^a	2841.1^b
T_2	451.43^a	3471.4^{ab}
T_3	280.20^a	3817.7^a
T_4	443.65^a	4059.0^a

Note: Different alphabets indicate significant difference between treatments by Duncan's New Multiple range Test (DNMRT) at p≤0.05.

To consolidate these findings a similar investigation on organic soils is suggested. Both greenhouse and field experiments using test crop such as *Z. mays* if retention of ammonium ion observed in the laboratory experiment will result in improved urea-N use efficiency and yield. About 3 to 5 cropping cycles need to be carried out to confirm the findings of this study on Nyalau Series.

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