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Full Length Research Paper

Effects of crude humin and compost produced from selected waste on *Zea mays* growth, nutrient uptake and nutrient use efficiency

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Waste from oil palm plantations, paddy fields, sawn timber and poultries are substantial. Inappropriate disposal of these wastes can cause environmental problems such as air and land pollutions. The objective of this study was to determine the effect of crude humin and compost produced from rice straw, rice husk, sawdust, and oil palm empty fruit bunch on growth, dry matter production, nutrient uptake and nutrient use efficiency of maize. Standard procedures were used to determine soil pH, total nitrogen, exchangeable ammonium, available nitrate, exchangeable phosphorus, cations, organic matter, total organic carbon and cation exchange capacity before and after planting. The plants were measured for diameter and height at tasselling stage prior to harvest. Dry matter production, nutrient uptake and nutrient use efficiency were also determined. Application of sawdust compost (T8) significantly increased maize plant diameter, height, dry matter production, and N, P and K uptake and use efficiency. It also reduced N, P and K based chemical fertilizer up to 90%. Application of humin and other selected waste composts (T6, T7 and T9) could be used as alternative for chemical fertilizers and their similar effects on maize plants.

Key words: Crude humin, *Zea mays*, nutrient uptake, nutrient use efficiency.

INTRODUCTION

Agriculture sector is the third important economy factor in the economic growth of Malaysia and it contributed in national gross domestic product (GDP) of RM 738.67 billion in year 2008. To sustain the production of agricultural commodities, Malaysia imports a lot of chemical fertilizers. The import of chemical fertilizer in Malaysia is increasing yearly. In 2008, the total import value of fertilizers were US$ 2.96 billion which include urea, phosphate rock, muriate of potash (MOP) and phosphate fertilizers (such as diammonium phosphate and triple super phosphate) amounted to US$ 169.4 million, US$ 309.7 million, US$ 1.14 billion and US$ 412.9 million, respectively (Sabri, 2009).

Wastes from oil palm plantations, rubber plantations, paddy fields sawn timber and poultries are substantial. Inappropriate disposal of these wastes can cause

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Table 1. Treatments eveluated in pot experiment using *Zea mays* as test crop.

Treatment	Urea (g)	ERP (g)	K Fertilizer (g)
T0	0.00	0.00	0.00
T1	4.84	7.45	2.48 MOP
T2	3.24	4.95	53.02 RS humin
T3	3.58	5.67	68.90 RH humin
T4	3.86	6.36	63.22 SD humin
T5	3.94	6.48	43.39 EFB humin
T6	2.92	4.51	50.95 RS compost
T7	0.83	0.00	164.46 RH compost
T8	0.26	1.07	227.48 SD compost
T9	3.71	5.31	53.05 EFB compost

environmental problems such as air and land pollution (Medina, 2010). These organic wastes can be transformed into beneficial forms through composting (Yu et al., 2007; Zeng et al., 2010). Composting is one of the better alternative ways in managing these organic wastes. Using of organic wastes also reduces chemical fertilizers usage and reduces environmental problems such as eutrophication due to leaching and deposition of nutrients from fertilizer water bodies (Mishima et al., 2010; Wang et al., 2011).

Composting of these selected wastes increases humic substances and nutrient contents through humification and mineralization (Moral et al., 2009; Nguyen et al., 2010). This makes compost beneficial for plants as a fertilizer. Although, use of composts as organic fertilizer (Evanylo et al., 2008) is well known, only few studies have been conducted on humin for plant nutrients. Besides humic acids (HA) and fulvic acids (FA), addition or application of humin from composted sago waste can also increase plant dry matter production, nutrient content, uptake and use efficiency (Petrus et al., 2010). This study was conducted to determine the effect of crude humin and compost produced from rice straw (RS), rice husk (RH), sawdust (SD), and oil palm empty fruit bunch (EFB) on growth, dry matter production, nutrient uptake, and nutrient use efficiency of *Zea mays*.

MATERIALS AND METHODS

Composts and crude humin used in this study were from a previous study. Bekenu series (Tipik Tualemkuts) was sampled at 0 to 25 cm in an undisturbed area of Universiti Putra Malaysia Bintulu Sarawak Campus, Malaysia. The soil was air-dried, and crushed to pass a 2 mm sieve. The soil was analyzed prior and at the end of the study for texture using hydrometer method (Tan, 2005); pH in distilled water and 1M KCl (at ratio of 1:2.5 soil:water or KCl) using a glass electrode (Peech, 1965); ash, organic matter and total organic carbon using loss-on-ignition method (Piccolo, 1996); total nitrogen using Kjedahl method (Bremner, 1965); available NO_3 and exchangeable NH_4 (Keeney and Nelson, 1982); available cations and phosphorus extracted using the Double Acid method (Tan, 2005) and cations determined using Atomic Absorption Spectometer (PerkinElmer AAnalyst 800). Phosphorus was determined using the Blue method (Murphy and Riley, 1962); CEC was determined by the leaching method (Cottenie, 1980) followed by steam distillation (Bremner, 1965).

The quantity of Bekenu series soil used was determined based on its bulk density and pot size [25 cm (top diameter) × 21 cm (bottom diameter) × 21 cm (height)]. About 8 kg of air-dried Bekenu series soil was weighed into pots. This study was carried out in a rain shelter at Universiti Putra Malaysia Bintulu Sarawak Campus in a randomized complete block design (RCBD) with 4 replications. Ten treatments involving humins from composts and composts itself were used in this study (Table 1). Maize seeds (var. Aurora 2 F1 hybrid), were soaked overnight in water for better germination and the soil was moistened up to 70% field capacity using tap water for 24 h prior to sowing. After 24 h, five maize seeds were sowed in each pot at 3 to 4 cm soil depth and closed with loosen soil for quick germination. At 7 days after sowing (DAS), the seedlings were thinned to one seedling per pot to provide enough space and nutrients for better growth.

Fertilizer requirement for the maize crop (60 kg ha^{-1} N, 60 kg ha^{-1} P_2O_5, 40 kg ha^{-1} K_2O) (MARDI, 1990) was scaled down to per plant basis equivalent [Urea (4.84 g $plant^{-1}$), Egyptian Rock Phosphate (ERP) (7.45 g $plant^{-1}$) and Muriate of Potash (MOP) (2.48 g $plant^{-1}$)]. Prior to fertilizer application, the fertilizer mixtures were weighed and mixed into 250 mL conical flask using orbital shaker at 200 rpm (Yusuff et al., 2009) for 30 min (Shamsuddin et al., 2009). For T1, the fertilizers were split into two equal applications at 10 and 28 DAS (conventional practice). For the treatments T2 to T9, the fertilizer mixtures were applied at 10 DAS only. The plants were monitored up to the tasselling stage (48 DAS). This was because tassel stage is the maximum growth stage of the plants before they enter productive stage (Kasim et al., 2009). Growth performance in terms of plant height was determined using measuring tape whilst stem diameter was measured at 10 cm above soil surface a using digital vernier caliper.

After harvesting, maize plants were partitioned into leaf, stem, tassel, and root. Plant samples were oven-dried at 60°C until a constant weight was attained. Prior to analysis, the oven-dried samples were ground using plant grinder. Total N content in plant samples were determined using Kjedahl method (Bremner, 1965),

Table 2. Selected chemical and physical properties of Bekenu series soil.

Property	Data Obtained (0-25 cm)	Paramananthan (2000) (0-36 cm)
pH(water)	4.41	4.6-4.9
pH(KCl)	3.25	3.8-4.0
CEC (cmol kg^{-1})	11.97	3.86-8.46
Total N (%)	0.08	0.04-0.17
Exchangeable NH_4^+ (mg kg^{-1})	21.02	nd
Available NO_3^- (mg kg^{-1})	7.01	nd
Available P (mg kg^{-1})	4.85	nd
Exchangeable K(cmol kg^{-1})	0.10	0.05-0.19
Exchangeable Ca (cmol kg^{-1})	0.25	0.01
Exchangeable Mg (cmol kg^{-1})	0.34	0.07-0.21
Exchangeable Na (cmol kg^{-1})	0.22	0.01
C/N Ratio	28.93	14-15
Ash content (%)	95.81	nd
Total Organic Matter (%)	4.19	nd
Total Organic Carbon (%)	2.43	0.57-2.51
Bulk density (g cm^{-3})	1.16	nd
Sand %	71.04	72-76
Silt %	14.58	8-9
Clay %	14.38	16-19
Texture	SCL	SCL

CEC, Cation exchange capacity; nd, not determined; SCL, sandy clay loam.

K and P were extracted using dry ashing (Cheftetz et al., 1996) and K content was determined using Atomic Absorption Spectrometer (AAS) (PerkinElmer AAnalyst 800) while P was determined using the Blue Method (Murphy and Riley, 1962). Nitrogen, P and K contents in plant parts were used to calculate their uptake and use efficiency. Nutrient use efficiency was calculated based on the following formula (Pomares-Gracia and Pratt, 1987):

$$\%\ \text{Fertilizer nutrient recovery} = \frac{(A) - (B)}{R} \times 100\%$$

Where, A = total plant nutrient uptake from fertilized soil (T1 to T9), B = total plant nutrient uptake from unfertilized soil (T0), R = rate of fertilizer nutrients applied, and Nutrient uptake = nutrient concentration (%) × dry weight (g).

Analysis of variance (ANOVA) was used to test treatments effect while means of the treatments were compared using Tukey's test. All analyses were conducted using Statistical Analysis System Version 9.2 (SAS. 2008).

RESULTS AND DISCUSSION

The selected chemical and physical properties of soil (Table 2) were typical of Bekenu series and were consistent with those reported by Paramananthan (2000) except for CEC, exchangeable calcium, magnesium and sodium.

Treatments effect on maize height and diameter at 48 DAS are presented in Table 3. T8 significantly affected plant diameter and height compared to T1 (conventional chemical fertilizer) and T0 (without fertilizer). The effect of T2, T3, T4, T5, T6, T7 and T9 were similar to T1 in terms of diameter and height of maize plant at 48 DAS. Treatment with saw dust compost (T8) significantly increased dry matter production in root and leaf compared to other treatments. T7, T8 and T9 had greater effect on stem and total dry matter production (Table 4). However, in terms of dry matter production treatments, humin (T2, T3, T4 and T5) and compost (T6, T7 and T9) were similar to plants applied with conventional fertilizer (T1).

Plants under T0 were stunted because of no fertilization. Lack of sufficient amount nutrients in unfertilized soils causes insufficient supply of nutrients to support plant growth and development. Significant effect of T8 on diameter and height caused significant increase in dry matter production regardless of plant part. This was because, application of sawdust compost increased organic matter, carbon and CEC of the soil (Table 7). Thus, the compost may have increased timely retention and nutrients release in the soil for plant uptake. This play an important role as it slows the of release fertilizer

Table 3. Effect of treatments on height and diameter of maize at 48 DAS

Treatment	Diameter (mm)	Height (cm)
T0	4.83^{c}	19.6^{c}
T1	8.95^{b}	97.9^{b}
T2	10.06^{ab}	129.5^{ab}
T3	10.41^{ab}	135.1^{ab}
T4	11.16^{ab}	123.5^{ab}
T5	11.26^{ab}	118.4^{ab}
T6	10.29^{ab}	122.1^{ab}
T7	11.79^{ab}	139.1^{ab}
T8	12.98^{a}	157.9^{a}
T9	10.93^{ab}	141.9^{ab}

Note: Different letters within a column indicate significant difference between means using Tukey's test at P=0.05.

Table 4. Effect of treatments on dry matter production of maize at 48 DAS.

Treatment	Root	Stem	Leaf	Total
	(g plant-^{1})			
T0	0.50^{c}	0.37^{d}	0.64^{c}	1.51^{d}
T1	1.99^{bc}	4.83^{cd}	3.58^{bc}	10.41^{cd}
T2	2.41^{abc}	6.78^{bc}	4.40^{b}	13.58^{bc}
T3	1.89^{abc}	5.69^{bc}	3.92^{b}	11.49^{bc}
T4	2.97^{abc}	7.45^{bc}	5.70^{b}	16.12^{bc}
T5	2.32^{bc}	6.85^{bc}	4.15^{bc}	13.31^{bc}
T6	3.76^{ab}	8.02^{bc}	5.86^{b}	17.65^{bc}
T7	4.00^{ab}	11.17^{ab}	6.42^{b}	21.58^{ab}
T8	5.61^{a}	13.84^{a}	10.07^{a}	29.51^{a}
T9	4.12^{ab}	11.00^{ab}	6.41^{b}	21.53^{ab}

Note: Different letters within a column indicate significant difference between means using Tukey's test at P=0.05.

(Zai et al., 2008) by preventing nutrient immobilization and continued supply of nutrients to the plant for better growth and development.

Different treatments effect on N, P and K uptake in maize plant at 48 DAS are shown in Table 5. Regardless of plant part, T8 had significant effect on N uptake compared to other treatments. T7 (rice husk compost) and T8 (sawdust compost) had greater effect on P uptake in root, stem and total of plant parts compared to other treatments. However, T8 had the highest P uptake in leaf of maize. Rice husk compost (T7), sawdust compost (T8) and EFB compost (T9) had greater effect on the sum of plant parts and stem K uptake. Potassium uptake in root was higher in T2, T6, T7, T8 and T9. T8 had the greater effect on K uptake in leaf compared to rest of the treatments.

Composts which are low in density (Calzolari et al., 2009) function as bulking agent and improve soil structure by loosening it and increase the porosity for aeration (Celik et al., 2010). It allows roots to get oxygen and increase in growth and penetration in soil. Hence, they increases root growth and root surface area. This enables roots to absorb water and nutrient from soil and enhance plant growth and development.

Effect of different treatments on N, P and K use efficiency of maize plant at 48 DAS is presented in Table 6. There was no significant N and K use efficiency in root regardless of treatment. Sawdust compost (T8) had the

Table 5. Treatments effect on N, P and K uptake of maize plant at 48 DAS.

Treatment	Root	Stem	Leaf	Total
N (g plant^{-1})				
T0	0.48^{c}	0.27^{c}	0.83^{c}	1.57^{c}
T1	1.74^{bc}	7.83^{bc}	10.14^{bc}	19.71^{b}
T2	1.84^{bc}	10.91^{b}	14.57^{b}	27.33^{b}
T3	2.02^{bc}	12.24^{b}	13.78^{b}	28.03^{b}
T4	1.90^{bc}	9.34^{b}	13.62^{b}	24.86^{b}
T5	1.56^{bc}	10.38^{b}	12.62^{b}	24.57^{b}
T6	2.56^{ab}	12.10^{b}	16.33^{b}	30.99^{b}
T7	2.28^{bc}	12.67^{b}	15.79^{b}	30.74^{b}
T8	4.53^{a}	23.25^{a}	30.93^{a}	58.71^{a}
T9	2.35^{bc}	13.07^{b}	10.87^{b}	26.30^{b}
P (g plant^{-1})				
T0	0.06^{d}	0.08^{c}	0.13^{c}	0.27^{d}
T1	0.33^{cd}	0.95^{b}	1.00^{bc}	2.28^{c}
T2	0.42^{bcd}	1.70^{b}	1.14^{b}	3.26^{c}
T3	0.40^{bcd}	1.37^{b}	1.14^{b}	2.91^{c}
T4	0.38^{bcd}	1.29^{b}	1.12^{c}	2.79^{c}
T5	0.29^{cd}	1.19^{b}	0.97b^{c}	2.44^{c}
T6	0.47^{bc}	1.42^{b}	1.33^{b}	3.21^{c}
T7	0.74^{ab}	2.73^{a}	1.61^{b}	5.08^{b}
T8	0.88^{a}	3.31^{a}	3.04^{a}	7.23^{a}
T9	0.58^{abc}	1.66^{b}	1.51^{b}	3.76^{bc}
K (g plant^{-1})				
T0	0.34^{b}	0.68^{d}	1.08^{c}	2.10^{d}
T1	3.33^{ab}	15.23^{c}	10.35^{bc}	28.91^{c}
T2	4.75^{a}	25.31^{abc}	16.64^{b}	46.70^{abc}
T3	4.30^{ab}	24.08^{abc}	16.48^{b}	44.85^{bc}
T4	3.80^{ab}	22.15^{bc}	18.26^{ab}	44.20^{bc}
T5	4.15^{ab}	22.40^{bc}	13.19^{b}	39.74^{bc}
T6	5.11^{a}	25.38^{abc}	15.68^{b}	46.18^{abc}
T7	7.28^{a}	31.96^{ab}	18.30^{ab}	57.53^{ab}
T8	6.80^{a}	36.16^{a}	29.66^{a}	72.62^{a}
T9	6.29^{a}	30.99^{ab}	19.32^{ab}	56.60^{ab}

Note: Different letters within a column indicate significant difference between means using Tukey's test at P=0.05.

highest effect on N use efficiency in stem, leaf and total of maize plant. T8 also had highest effect on P and K use efficiency in leaf at 48 DAS. Maize plant applied with rice husk compost (T7) and sawdust compost (T8) had significant P use efficiency in root and stem with higher P and K use efficiency in total plant. T7, T8 and T9 had significantly higher K use efficiency in stem compared to T1.

Moreover, composts contain more HA and FA than humins. This is because, HA and FA was removed from humins during isolation. Hence, plants applied with composts had greater N, P and K uptake and use efficiency. A previous study showed that HA application at rate of 1 g kg^{-1} soil increased nutrient uptake in plant (Asik et al., 2009) and this observation was consistent with that of T8 where, application of sawdust compost supplied 1.2 g HA kg^{-1} soil and this might be the main

Table 6. Treatments effect on N, P and K use efficiency of maize plant at 48 DAS.

Treatment	Root	Stem	Leaf	Total
N (%)				
T0	nd	nd	nd	nd
T1	56.58[a]	338.9[b]	417.4[b]	812.8[b]
T2	61.14[a]	477.3[ab]	616.2[ab]	1154.6[ab]
T3	68.72[a]	536.7[ab]	580.7[ab]	1186.1[ab]
T4	63.55[a]	406.5[ab]	573.6[ab]	1043.7[ab]
T5	48.55[a]	453.6[ab]	528.7[ab]	1030.8[ab]
T6	93.32[a]	530.6[ab]	694.8[ab]	1318.7[ab]
T7	80.52[a]	555.9[ab]	670.8[ab]	1307.3[ab]
T8	122.41[a]	694.3[a]	909.1[a]	1725.8[a]
T9	83.88[a]	574.2[ab]	450.2[b]	1108.3[ab]
P (%)				
T0	nd	nd	nd	nd
T1	12.10[c]	39.17[b]	39.22[b]	90.48[c]
T2	16.38[bc]	72.48[b]	45.52[b]	134.37[c]
T3	15.30[bc]	57.71[b]	45.44[b]	118.45[c]
T4	14.30[bc]	54.25[b]	44.59[b]	113.14[c]
T5	10.29[c]	49.66[b]	37.64[b]	97.58[c]
T6	18.69[bc]	59.81[b]	53.70[b]	132.20[c]
T7	30.82[ab]	118.93[a]	66.20[b]	215.95[b]
T8	36.84[a]	144.78[a]	130.69[a]	312.31[a]
T9	23.53[abc]	70.87[b]	62.08[b]	156.48[bc]
K (%)				
T0	nd	nd	nd	nd
T1	2.01[a]	9.77[b]	6.22[b]	17.99[c]
T2	2.96[a]	16.53[ab]	10.44[b]	29.94[abc]
T3	2.66[a]	15.70[ab]	10.33[b]	28.93[abc]
T4	2.32[a]	14.41[ab]	11.53[ab]	28.26[bc]
T5	2.56[a]	14.58[ab]	8.13[b]	28.26[bc]
T6	3.20[a]	16.58[ab]	9.80[b]	29.58[abc]
T7	4.66[a]	20.99[a]	11.55[ab]	37.20[ab]
T8	4.34[a]	23.81[a]	19.18[a]	47.33[a]
T9	4.00[a]	20.34[a]	12.24[ab]	36.58[abc]

Note: Different letters within a column indicate significant difference between means using Tukey's test at P=0.05; nd: not determined.

reason why T8 had greater effect on N, P and K uptake and use efficiency. Higher content of carboxylic, phenolic, hydroxylic and other functional groups in HA and FA functions as nutrient chelator (Akin, 2011, Reynolds, 2010 and Pinton et al., 2009). Moreover, HA and FA had higher total acidity which is similar to CEC where they can hold nutrients at the exchange site (functional groups) and releases slowly for plant uptake and prevent from losses through ammonia volatilization and leaching.

Conclusion

Application of sawdust compost (T8) significantly

Table 7. Selected soil chemical properties at 48 DAS.

Property	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9
pH_{water}	4.81^{c}	4.51^{d}	5.01^{b}	5.20^{a}	5.05^{ab}	4.80^{c}	4.69^{c}	5.01^{b}	5.06^{ab}	5.13^{ab}
pH_{KCl}	3.64^{d}	3.69b^{cd}	3.72^{abcd}	3.82^{a}	3.72^{bcd}	3.68^{bcd}	3.65^{cd}	3.75^{abc}	3.76^{ab}	3.75^{abc}
Ash (%)	96.00^{a}	95.75^{ab}	95.65^{ab}	95.25^{abc}	95.00^{bc}	95.45^{abc}	95.45^{abc}	94.60^{c}	92.05^{d}	95.35^{abc}
OM (%)	4.00^{d}	4.25^{cd}	4.35^{cd}	4.75^{bcd}	5.00^{bc}	4.55^{bcd}	4.55^{bcd}	5.40^{b}	7.95^{a}	4.65^{bcd}
TOC (%)	2.32^{d}	2.47^{cd}	2.52^{cd}	2.76^{bcd}	2.90^{bc}	2.64^{bcd}	2.64^{bcd}	3.13^{b}	4.61^{a}	2.70^{bcd}
Total N (%)	0.11^{c}	0.12^{bc}	0.13^{abc}	0.12^{bc}	0.13^{abc}	0.11^{c}	0.13^{abc}	0.15^{ab}	0.16^{a}	0.13^{abc}
Exchangeable NH_4^+ (mg kg^{-1})	40.28^{b}	99.83^{a}	22.77^{b}	22.77^{b}	35.03^{b}	21.02^{b}	19.27^{b}	17.52^{b}	33.28^{b}	21.02^{b}
Available NO_3^- (mg kg^{-1})	22.77^{bc}	21.02^{bc}	26.27^{bc}	19.27^{bc}	24.52^{bc}	29.77^{bc}	17.52^{c}	15.76^{c}	47.29^{a}	35.03^{ab}
Exchangeable P (mg kg^{-1})	1.68^{d}	49.74^{a}	30.36^{cb}	48.58^{a}	47.84^{ab}	50.96^{a}	28.91^{c}	30.74^{bc}	37.82^{abc}	39.26^{abc}
Exchangeable K (cmol kg^{-1})	0.09^{d}	0.29b^{c}	0.28^{bc}	0.63^{a}	0.27^{bc}	0.30^{bc}	0.29^{bc}	0.38^{b}	0.25^{c}	0.34^{bc}
Exchangeable Ca (cmol kg^{-1})	0.09^{d}	0.58^{abc}	0.33^{cd}	0.79^{a}	0.80^{a}	0.42^{bc}	0.39^{bc}	0.72^{a}	0.75^{a}	0.61^{ab}
Exchangeable Mg (cmol kg^{-1})	0.30^{d}	0.31^{d}	0.72^{b}	0.68^{bc}	0.53^{c}	0.54^{bc}	0.51^{c}	1.23^{a}	1.14^{a}	0.68^{bc}
Exchangeable Na (cmol kg^{-1})	0.17^{c}	0.23^{b}	0.21^{bc}	0.22^{b}	0.21b^{c}	0.20^{bc}	0.22^{b}	0.30^{a}	0.29^{a}	0.21^{bc}
CEC (cmol kg^{-1})	10.93^{bc}	9.80^{c}	12.05^{ab}	11.50^{abc}	11.58^{abc}	11.83^{abc}	12.53^{ab}	13.30^{a}	13.73^{a}	11.70^{abc}

Note: Different letters within a row indicate significant difference between means using Tukey's test at P=0.05.

increased maize plant diameter, height, dry matter production, and N, P and K uptake and use efficiency. It also reduced N, P and K based chemical fertilizer up to 90%. Application of humin and other selected waste composts (T6, T7 and T9) can be used as alternative for chemical fertilizers and their similar effects on maize plants.

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