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Quality Enhancement of Humid Tropical Soils after Application of Water Hyacinth (*Eichornia crassipes*) Compost

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Compost application to soil leads to the improvement of its properties. However, nutrient content and enhancing capacity of compost are highly dependent on the original source and additive. The purpose of the experiment was to investigate selected soil quality indicators' improvement and sweet corn growth following application of water hyacinth compost. Greenhouse experiment was carried out using Completely Randomized Design with 2 factors. First factor consisted of soils from humid tropics, i.e. Andepts, Udepts, and Udults and second factor comprised of water hyacinth compost rates, i.e. 0, 5, 10, 15, 20, and 25 Mg ha^{-1}. Treatment combinations were replicated 3 times. Compost was incorporated in soil a week before planting of sweet corn. After reaching maximum sweet corn growth, soil sample was collected, air-dried, grinded and passed through 0.5 mm screen, and analyzed for selected soil properties, except microbial biomass carbon (MBC) and particulate organic matter carbon (POMC) which were analyzed using fresh soil samples. The experiment pointed out that application of water hyacinth compost on Udepts exhibited the highest total soil organic carbon (TSOC), MBC, soil pH and available P (Bray I), followed by those in Andeps and Udults. Particulate organic matter carbon (PMOC), however, was highest in Andepts as compared to other soils. Higher rates of compost application contributed higher increase in TSOC, MBC, soil pH, available P, and exchangeable K. Udults had more pronounced increase in soil pH and decline of exchangeable Al than other soils. Pearson correlation analysis showed that the most distinct correlation among soil properties was observed between exchangeable Al and soil pH, followed by TSOC and MBC with coefficient correlation of -0.91 and 0.85, respectively. Correlation between soil properties and sweet corn growth exhibited that the most prominent correlation was shown between available P and shoot dry weigh of sweet corn with coefficient correlation of 0.92. This indicates that soil available P has significant contribution on sweet corn growth.

Keywords: water hyacinth compost, *Eichornia crassipes*, humid tropical soil, Andepts, Udults

Introduction

Organic farming system is an alternative solution of soil degradation due

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to over-use and prolong application of synthetic agrochemicals usually practiced in conventional system. This organic farming practice takes benefit mostly from organic fertilizer for its nutrient availability. A number of researchers have reported that use of organic fertilizer has enhanced soil quality. However, the benefit of organic fertilizer is highly dependent on its original sources. Lim et al. (2010) concluded that different source of compost had to be taken into consideration for its application guidelines. Hose et al. (2012) also reported that farmyard compost had 26% organic content, 8667 mg kg^{-1} nitrogen (N), 2033 mg kg^{-1} phosphorus (P), 4900 mg kg^{-1} potassium (K) and C/N ratio of 16.6. Another researcher pointed out that municipal waste compost had 32.9%, 7900 mg kg^{-1} P, 16000 mg kg^{-1} K, 95000 mg kg^{-1} calcium (Ca) (de Varennes *et al.*, 2012).

Compost and vermicompost provide significant improvement on soil quality. Dairy manure compost has significant increase in soil quality as indicated by organic matter content, pH and Electrical Conductivity (EC), concentration of nitrate nitrogen (NO_3-N), phosphorus (P), and exchangeable potassium (K) of Alfisol from Texas USA (Butler *et al.* 2009). Other study also points out that application of poultry manure in conservation tillage increases soil organic carbon (SOC) and total nitrogen (N) as well as soil enzymes at surface soil (Mankolo *et al.*, 2012). Compost and vermicompost also significantly increase SOC, total N, soil pH, EC and reduce bulk density of soil (Jouquet *et al.*, 2011; Arthur *et al.* 2012). Vermicompost combined with liquid organic fertilizer also provides distinct increase in NO_3-N, available P, exchangeable K, soil pH and reduction of exchangeable Al to the depth of 20-25 cm depth of soil, but P (Muktamar *et al.* 2015).

Compost from weed is also reported to bring about enhancement of soil quality and plant growth. Previous study carried out by Wahyudi *et al.* (2010) exhibited that application of tithonia and gliricidia compost on Ultisol provided significant increase in soil pH and reduction of exchangeable aluminum (Al). Another study revealed that content of SOC, Ca, Mg, K and total N of soil fertilized with cromolaena compost was higher than that of cattle manure (Suntoro *et al.*, 2001). Improvement of soil quality after application of weed compost often leads to increase growth and yield of crop. Previous studies indicated that application of Wedelia, Tithonia, and Cromolaena compost increased growth and yield of crops (Setyowati *et al*. 2008; Iqua and Huasi, 2009; Setyowati *et al*., 2014) and could substitute for synthetic fertilizer in crop production (Setyowati *et al*. 2015; Muktamar *et al.* 2016).

Water hyacinth is another alternative for compost material. Such weed dry matter contains 22.99% protein, 0.14% Ca, 0.6% P, 2.3% N, and 4.2% ash (Suntoro *et al.*, 2001). Another researcher points out that water hyacinth dry matter has 1.5% N, 0.74% P, 5.7% K (Vidya and Girish, 2014). Water hyacinth compost application is reported to enhance growth and yield of tomato (Mashavira et al., 2015), coriander (*Coriandrum sativum*) (Lata and Dubey, 2013), spinach (Sanni and Adesina, 2012), green mustard (Lata and Veebapani, 2011), and cabbage (Mashavira, 2014). Application of compost of water hyacinth does not have an effect on yield corn even though improves its growth (Osoro et al., 2014).

The purpose of the experiment was to investigate selected soil quality indicators' improvement and sweet corn growth following application of water hyacinth compost.

Materials and methods

Experimental Design and Compost Preparation

Greenhouse experiment was conducted from September 2015 to February 2016, arranging in Completely Randomized Design (CRD) with 2 factors. First factors were three soil types, i.e. Andepts, Udepts, and Udults and second factors were rates of water hyacinth compost, i.e. 0, 5, 10, 15, 20, and 25 Mg ha^{-1}. Treatment combination was replicated 3 times.

Water hyacinth compost was prepared by mixing of leaves and Effective Microorganism (EM-4). The EM-4 solution was a mixture of 50 ml EM4 and 10 g sugar in 2000 ml aquadest. Approximately 100 kg of water hyacinth leaves were sliced into 5 cm long and placed in 2x2x0.5 m^3 wooden box, thereafter was sprayed with EM-4 solution. The mixture was covered with plastic and incubated for 70 days. The mixture was reversed every week and watered when required. After incubation, the compost was sieved with 2 mm screen and it was ready for application. Water hyacinth compost had 27.2% organic-C, 2.16% N, 1.71% P, 1.09% K, and ph of 7.9.

Soil Collection and Treatment Preparation

Soil samples were collected from three different sites, representing different altitudes. Each soil had different characteristics. First soil sample was Andepts from Air Duku Village, Rejang Lebong District located at latitude 3^{o} 27'34.26" S and longitude 102^{o}36'54.95" at elevation of 1054 m above sea level. The soil in the site has continuously been cropped to organic vegetables since 2011. Each season soil was fertilized with 15 Mg ha^{-1} organic fertilizer and no additional synthetic fertilizer was applied. Andepts surface soil contained 24.0 g kg^{-1} TSOC, 16.02 mg kg^{-1} available P, 241.8 mg kg^{-1}

exchangeable K, 1.46 g kg^{-1} MBC, 0.51 g kg^{-1} POMC, 14.1 mg kg^{-1} exchangeable Al and soil pH of 5.2.

Second soil sample was Udepts from Tebat Monok Village, Kepahiang District located at latitude 3^o 39’ 16.1” S and longitude 102^o 34’ 26.9” E at elevation of 519 m above sea level. The soil in the site was fertilized with coffee bean compost at rate of 40 Mg ha^{-1} for two seasons before soil sample was collected. Udepts surface soil had 24.7 g kg^{-1} TSOC, 59.79 mg kg^{-1} available P, 70.2 mg kg^{-1} exchangeable K, 2.93 g kg^{-1} MBC, 0.52 g kg^{-1} POMC, 36.0 mg kg^{-1} exchangeable Al and soil pH of 5.6.

The third soil sample was Udults from Kandang Limun Village, Bengkulu City located at latitude 3^o 45’ 10.9” S and longitude 102^o 17’ 0.20” E at elevation of 15 m above sea level. Site was a bare soil dominated with reed weed for more than a year. Udults surface soil contained 24.0 g kg^{-1} TSOC, 9.96 mg kg^{-1} available P, 66.3 mg kg^{-1} exchangeable K, 1.46 g kg^{-1} MBC, 0.40 g kg^{-1} POMC, 113 mg kg^{-1} exchangeable Al and soil pH of 4.50.

Composite soil sample at depth of 0-20 cm was collected from each site, afterward air-dried and sieved with 5 mm screen. Ten kg of soil was incorporated with water hyacinth compost corresponding to each treatment and put into polybag. The mixture was incubated for one week and kept moist by watering when required.

Greenhouse Experiment

After a week of soil and compost incorporation, 2 sweet corn seeds were planted to each polybag, thinning to only one healthier plant after one week of planting. No additional synthetic fertilizer was applied, leading to only take benefit of the compost for nutrient availability to plant. The growing media was watered every day to keep soil in moist condition. The experiment ended when maximum growth of sweet corn was achieved. Sweet corn plant was cut after plant height was measured. The shoot, then, was dried at 65-70^{o}C for 2 days and weighed for shoot dry weight.

Fresh soil sample was analyzed for MBC by fumigation- titration method and POMC by physical fractionation (Cambardella and Elliot, 1992). Remaining soil was air-dried, sieved with 0.5 mm screen and analyzed for TSOC (Walky and Black), exchangeable Al (neutral salt extraction by Thomas, 1982), available P (Bray I), exchangeable K (ammonium acetate extraction and flame photometer), and soil pH (electrometric using pH meter at water and soil ratio of 1:1 by weight).

Statistical Analysis

Data were subjected to analysis of variance using PROC GLM in Statistical Analysis System version 9.1.3 portable at P < 0.05. Soil types differences was separated using Duncan's Multiple Range Test and LOF treatment means were compared using orthogonal polynomial at probability level of 0.05.

Results and Discussion

Application of water hyacinth compost had significant effect on soil quality indicator and growth of sweet corn as indicated in Table 1 but water hyacinth compost had no significant effect on POMC. Distinct difference of soil quality was also observed among three soils used in the experiment. The difference was mainly associated with inherent characteristics of each soil. First soil (Andepts) was collected from area with high influence of volcano activities and cropped to organic vegetables crops since 2011. Second soil (Udepts) was intensively managed and had been fertilized with high rate of organic fertilizer, while the third soil (Udults) was relatively unfertile soil.

Table 1. Analysis of variance for soil properties and growth of sweet corn.

Variables	Probability F < 0.050		
	Soil	Compost	Interaction
Total Soil Organic Carbon	< 0.0001	< 0.0001	< 0.0001
Particulate Organic Microbial Carbon	0.0097	0.8580	0.9646
Microbial Biomass Carbon	0.0089	0.0420	0.9989
Exchangeable Al	< 0.0001	0.0030	0.0125
Soil pH	< 0.0001	< 0.0001	< 0.0001
Available P (P-Bray I)	< 0.0001	< 0.0001	0.0061
Exchangeable K	< 0.0001	0.0029	0.1685
Plant Height	< 0.0001	0.0015	0.3315
Shoot Dry Weight	< 0.0001	0.0001	0.2012

Effect of water hyacinth compost on soil quality

The experiment showed that Udepts had highest TSOC, followed by Andepts and Udults (Figure 1). This was somehow related to high application of coffee bean compost at rate of 40 Mg ha^{-1} for the last two seasons before soil collection, leading to high concentration of organic carbon in soil. Study by Pujianto (2007) pointed out that coffee waste had high organic carbon, CEC, water retention, and phosphorus. Meanwile, Andepts was cropped to organic vegetable since 2011 with fertilization of vermicompost at rate of 15 Mg ha^{-1} each season while Udults was from site dominated with reed weed for more than a year. Ultisol inherently has low soil organic carbon (Adijaya and Made, 2014). When compared to initial content, only did Udepts have higher TSOC with application of water hyacinth compost, indicating that decomposition of organic matter was lower than that of addition, while the other two soils exhibited vice versa.

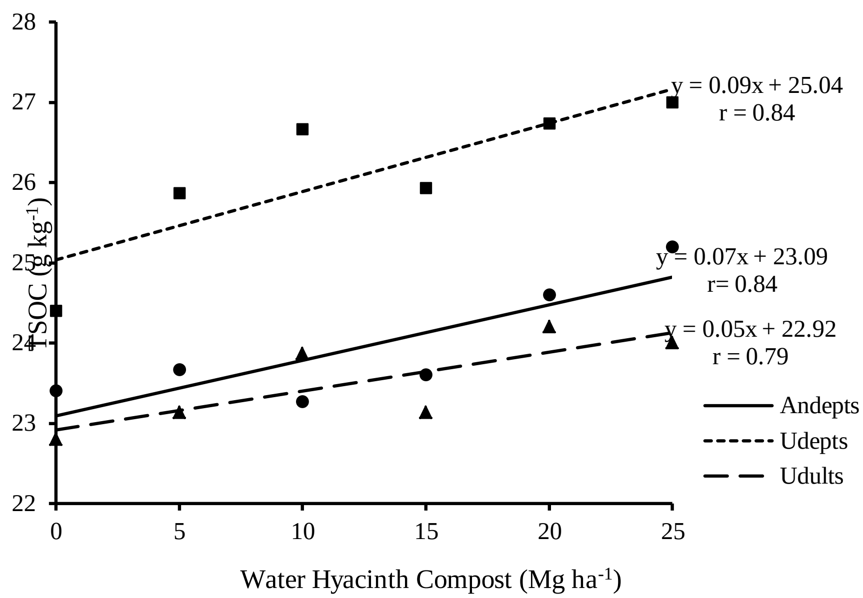

Figure 1. Total soil organic carbon of tropical soils as affected by water hyacinth compost

Higher rates of water hyacinth compost application resulted consistently linear increase in TSOC for all soils, with r 0.79 or higher (Figure 1), even though each soil had different increment as indicated from slopes of graph lines. Total soil organic carbon increased by 7.7%, 10.7%, and 5.3% for Andepts, Udepts, and Udults, respectively, when soil was fertilized with particular compost at rate of 25 Mg ha^{-1} as compared to that of control. The result was correspond to that concluded by Khan and Sanwar (2002) where addition of water hyacinth compost on loamy soil increased soil organic carbon and CEC.

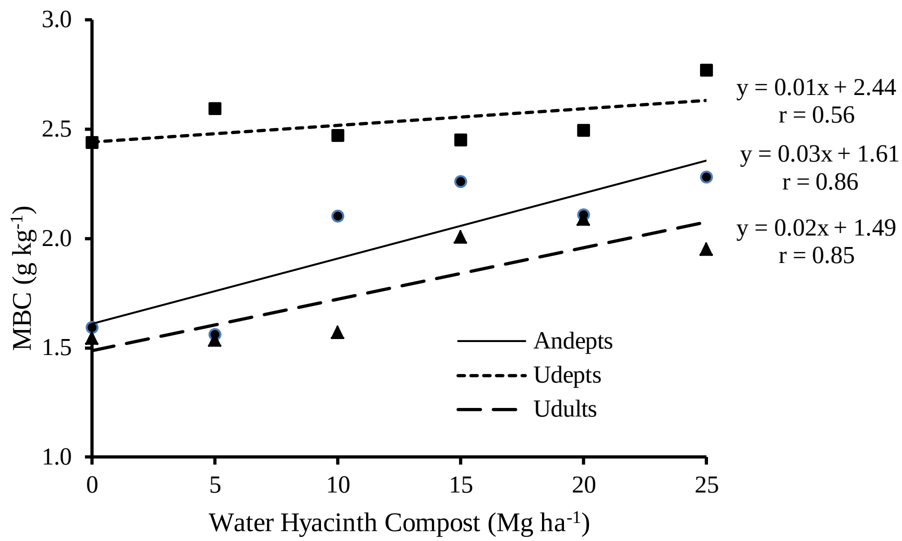

Figure 2. Microbial Biomass Carbon (BMC) of Andepts, Udepts, and Udults as influenced by water hyacinth compost

Similar trend was observed for biomass microbial carbon where water hyacinth compost application up to rate of 25 Mg ha^{-1} linearly increased MBC of soil (Figure 2). The trend was similar to that TSOC, indicating that MBC was mainly associated with soil organic carbon content in soil as also concluded by Liu *et al.* (2013) that MBC raised with increasing soil organic carbon. As TSOC, Udepts had highest MBC, followed by Andepts and Udults; however, Andepts and Udults have better response to the application of water hyacinth compost than Udepts. This finding indicates that soil with low content of TSOC leads to higher increment of MBC with increasing application of particular compost. Baaru *et al.* (2007) also reported that incorporation of organic resources to soil had distinct increase in MBC as compared to control. The portion of MBC in the soil organic carbon varied from 6.7% to10.3% which was higher than that reported by Ananyeva *et al*. (2009) where the portion of MBC in forest soil ranged from 1.3% to 5.4%. In addition, higher increase of MBC portion was observed at lower content of TSOC.

Application of water hyacinth compost did not significantly influence POMC of soil, but soil types did (Figure 3). Unlike MBC, Andepts contained highest POMC followed by Udepts and Udults. High content of POMC in Andepts might be associated with that Andepts was cropped to organic vegetables for more than 6 years (Muktamar *et al.* 2016) at 1054 m above sea level. Cambardella and Elliot (1992) pointed out that elevation and land slope had effect on POMC. On the other hand, Udults was collected from fallow site dominated with reed weed at elevation of 15 m above sea level. Figure 3 also showed that water hyacinth compost had no distinct effect on POMC. Liu et al. (2013) observed different result where long term effect of manure had significant increase in POMC.

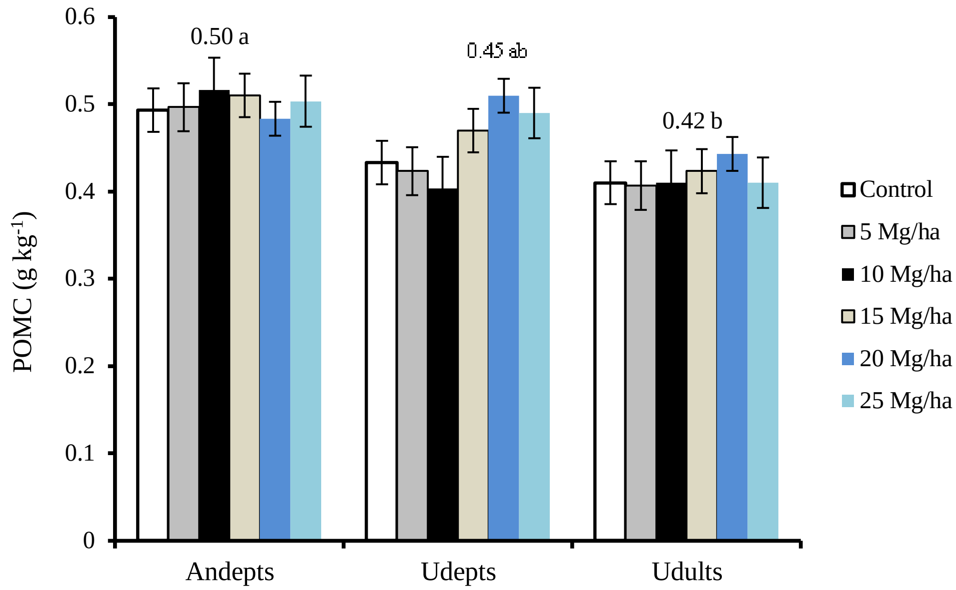

Figure 3. Particulate organic matter carbon (POMC) of Andepts, Udepts, and Udults under different rates of hyacinth compost.

Application of water hyacinth compost up to the rate of 25 Mg ha^{-1} linearly reduced exchangeable Al and soils studied in the experiment had significant differences of exchangeable Al as indicated in Figure 4. Moreover, Udult had greatest exchangeable Al, followed by Udepts and Andepts. Udults was naturally acid soil with high exchangeable Al (113 mg kg^{-1}) and low pH (4.5) while the other two soils had low Al saturation. Reduction of exchangeable Al due to application of compost was related to soil organic content as shown in Figure 1, 2, and 3. Humic substance released during mineralization of soil organic material contains active functional groups such as carboxyl and phenolic groups, leading to formation of organo-metalic complex (Spark, 2003), such as Al, causing lower exchangeable Al in soil. Previous study concluded that addition of humic substance extracted from organic material pronouncedly reduced Al concentration in soil (Winarso *et al*., 2010;

Ifansyah, 2013). Other study also resulted in decreasing exchangeable Al when acid soil was treated with citric and oxalic acid (Muktamar *et al.* 1998).

Reduction of exchangeable Al in relation to increasing rate of water hyacinth compost is more pronounced for Udults as compared to Andepts and Udepts, as indicated from slope of graph line in Figure 4. Application of compost at rate 25 Mg ha^{-1} declines 272.1% exchangeable Al for Udults as compared to control as well as 100% and 102.9% for Andepts and Udepts, respectively. This indicates that Udults, which is inherently acid, is more responsive to addition of compost than other two soils. This result is in concurrent to that reported by Opala *et al.* (2012) where addition of tithonia reduced 264.7% exchangeable Al as compared to control.

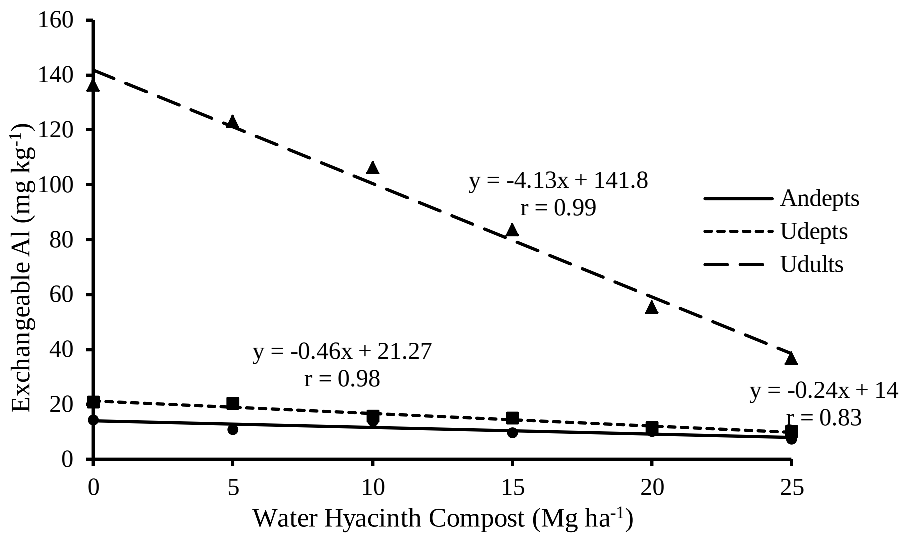

Figure 4. Effect of water hyacinth compost on exchangeable Al of Andepts, Udepts, and Udults

Reduction of exchangeable Al as water hyacinth compost rate increases was followed by improvement of soil pH (Figure 5). Formation of complex Al-humic substance leads to lower hydrogen production from Al hydrolysis in soil, thereafter increasing soil pH. Previous studies pointed out that application of organic fertilizer raised soil pH (Muktamar, 1998; Valarini *et al*. 2009). In addition, Udepts had greatest soil pH followed by Andepts and Udults. However, Increment of soil pH is highest for Udults, suggesting that this soil is highly responsive to increasing rates of compost. Soil pH of Udults increases by 27.59% as rate of compost increase from control to 25 Mg ha^{-1} while Andepts and Udepts are only 11.80 and 5.73%, respectively.

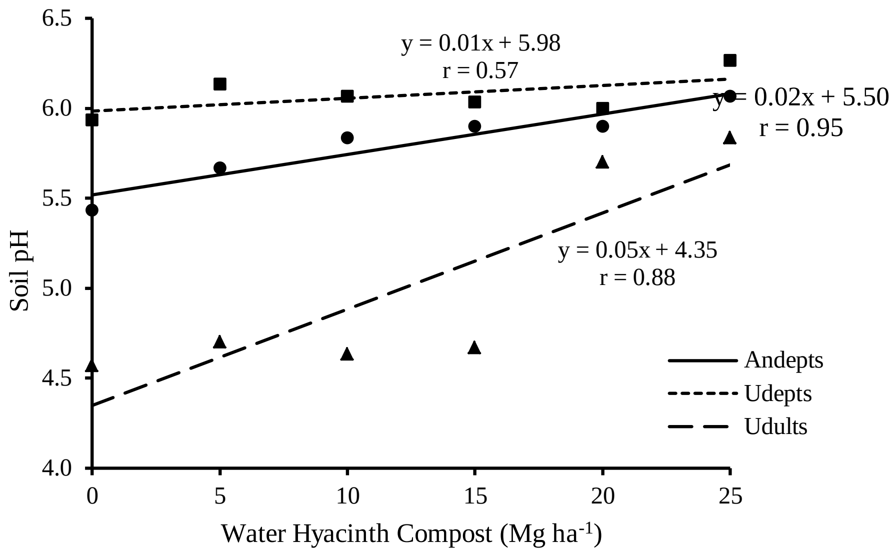

Figure 5. Soil pH of Andepts, Udepts, and Udults under different rates of water hyacinth compost.

Figures 6 and 7 indicated that application of water hyacinth compost exhibited significant increase in available P and exchangeable K for all soils studied in the experiment. However, Udults showed highest increment of available P and exchangeable K as rates of compost raise. Upon decomposition, compost releases macro and micro nutrient such as P and K. In addition, as compost application rate increased, available P and exchangeable K also increased. Earlier study suggested that application of municipal compost linearly increased available P on calcareous soil (Hosseinpur *et al.*, 2012). Another study carried out by Liu *et a*l. (2013) resulted increase in available N, P, and K content in soil treated with composted pineapple residue return.

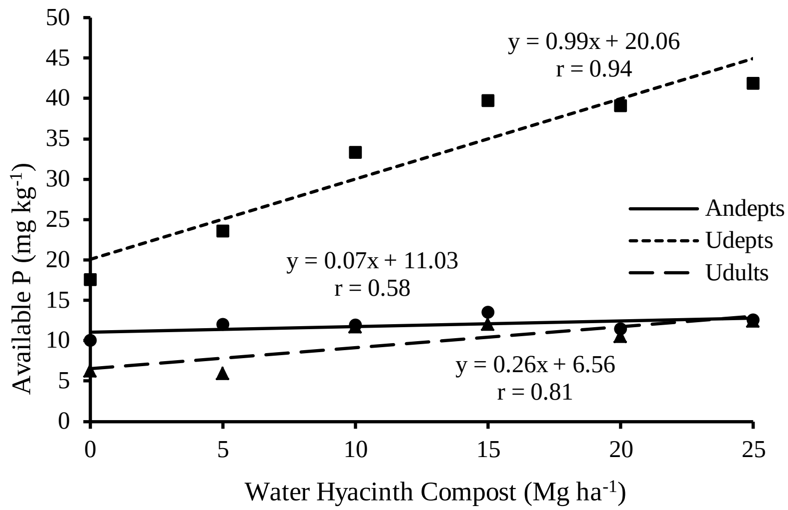

Figure 6. Soil available P in Andept, Udepts, and Udults as influenced by application of water hyacinth compost.

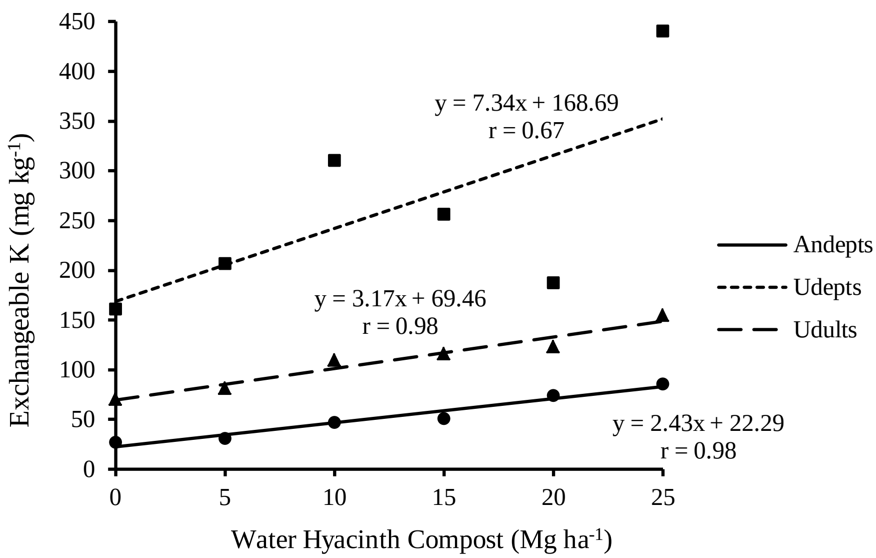

Figure 7. Effect of water hyacinth compost on exchangeable K in Andepts, Udepts and Udults

Figures 6 and 7 also showed that Udepts had greatest increment of available P and exchangeable K as compared to the other soils. This phenomenon is different from other soil properties determined in this experiment. Udults has very good response on BMC, exchangeable Al, and soil pH to application of water hyacinth compost. This might be associated with low fertility of this soil as indicated by high exchangeable Al and low soil pH. In term of P available P and exchangeable K, higher content of TSOC leads to higher P and K release during its mineralization.

Application of water hyacinth compost provides enhancement of soil quality as indicated by increase in TSOC, MBC, soil pH, available P, exchangeable K and reduction of exchangeable Al. A number of researchers concluded that soil organic carbon, microbial biomass carbon and microbial biomass nitrogen were often used as soil quality indicators (Islam and Weil, 2000; Ochiai *et al*., 2008; Adeboye *et al*., 2011; Amighi *et al.*, 2013). This indicated that application of water hyacinth compost was also capable to increase soil quality.

Pearson correlation shows that most soil properties examined in the experiment has correlation to each other, but POMC (Table 2). The most distinct correlation among soil properties was observed between exchangeable Al and soil pH with coefficient correlation of -0.91. High negative correlation between exchangeable Al and soil pH suggests that high Al hydrolysis in soil roots to increase in hydrogen concentration contributing to lower soil pH. The second prominent correlation among soil properties is MBC and TSOC with coefficient correlation of 0.85. Significant correlation between MBC and TSOC indicates that concentration of TSOC in soil plays extremely important role in enhancing activity of soil microorganism.

Table 2. Pearson correlation among soil properties and sweet corn growth variables

	MBC	POMC	Exc-Al	Soil pH	P-Bray	Exc K	PH	SDW
TSOC	0.85**	0.21^{ns}	- 0.55*	0.71**	0.79**	0.72**	0.87**	0.81**
MBC		0.43^{ns}	- 0.68**	0.80**	0.70**	0.60*	0.84**	0.74**
POMC			- 0.66*	0.49*	0.19^{ns}	$- 0.16^{ns}$	0.19^{ns}	0.29^{ns}
Exc Al				- 0.92**	- 0.48*	$- 0.24^{ns}$	- 0.50*	- 0.60**
Soil pH					0.60**	0.46ns	0.66*	0.71**
P-Bray						0.86**	0.87**	0.92**
Exc K							0.71**	0.79**
PH								0.82**

TSOC = Total Soil Organic Carbon; MBC = Microbial Biomass Carbon; POMC = Particulate Organic Matter Carbon; Exc Al = Exchangeable Aluminum; Exc K = Exchangeable Potassium; PH = Plant Height; SDW = Shoot Dry Weight, ns non significant, *significant at 0.05 probability level, **significant at 0.01 probability level.

Effect of Water Hyacinth Compost on Sweet Corn Growth

Enhancement of soil quality lead to the improvement of sweet corn growth as indicated by plant height and shoot dry weight. Figures 8 and 9 showed that application of compost linearly increased plant height and shoot dry weight. This result is in agreement with that investigated by Osoro *et al.* (2014) where water hyacinth compost significantly increased plant height, shoot dry weight and root dry weight of corn. Least prominent increment of plant height was observed in sweet corn grown in Udults and reversal was true for shoot dry weight of sweet corn.

Water hyacinth compost rate of 25 Mg ha^{-1} enlarged shoot dry weight by 50.10%, 45.30% and 216.89% for Andepts, Udepts and Udults, respectively in comparison to that control. This might be associated with pronounced reduction of Al and increase of soil pH in Udults after application of particular compost, leading to better growth environment. This indicates that sweet corn has high response to water hyacinth compost when grown in Udults.

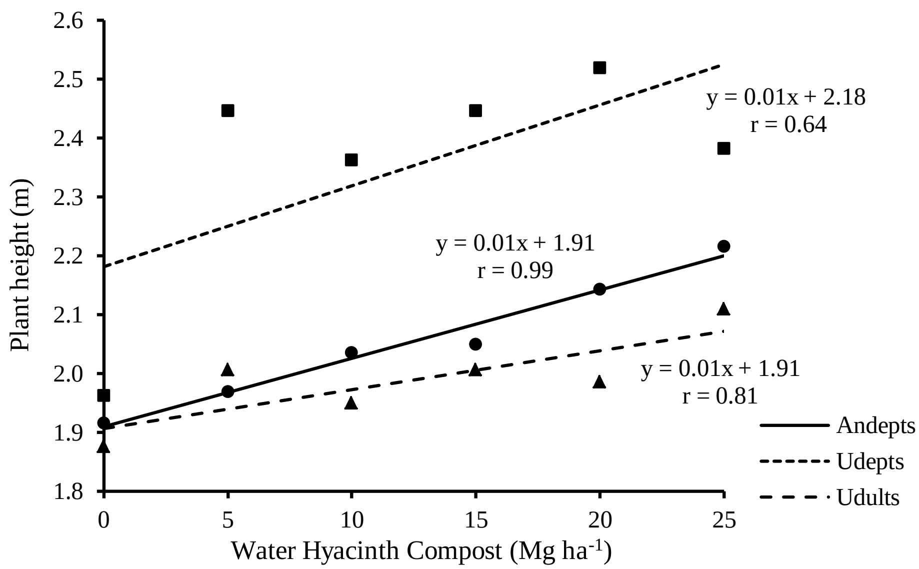

Figure 8. Water hyacinth compost influence on plant height of sweet corn.

Table 2 also showed that soil available P was significantly related to sweet corn height and shoot dry weight with coefficient correlation of 0.83 and 9.2, respectively. The correlation suggested that soil available P highly contributed to sweet corn growth. Total soil organic carbon was also pronouncedly related to plant height and shoot dry weight of sweet corn with coefficient correlation of 0.87 and 0.87, respectively. Upon mineralization of soil organic matter will release plant nutrients, thereafter available to the plant.

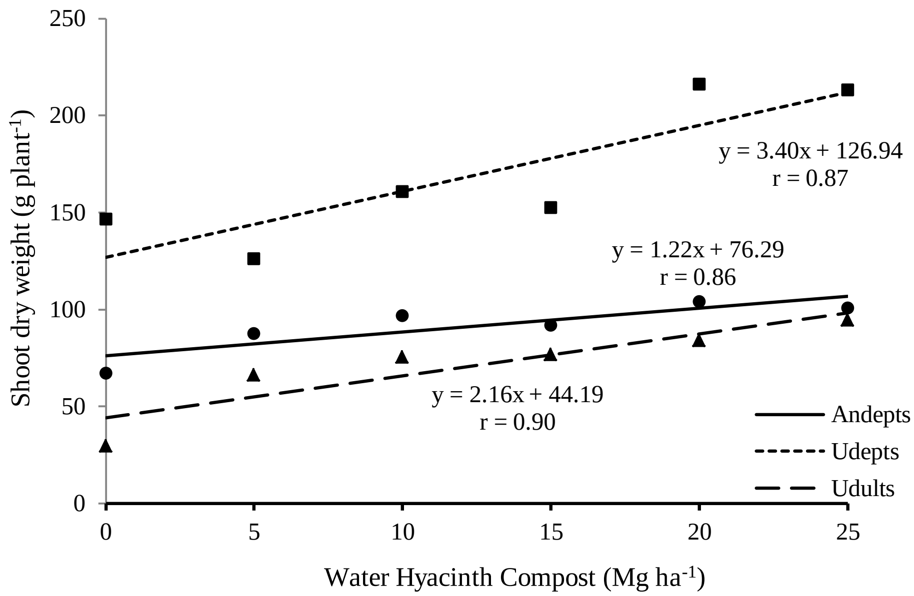

Figure 9. Effect of water hyacinth compost on shoot dry weight

Conclusion

Application of water hyacinth compost provided distinct increase in soil quality as indicated by enhancement of TSOC, MBC, soil pH, available P, exchangeable K and reduction of exchangeable Al. Udepts exhibited greatest TSOP, MBC, soil pH, available P, and exchangeable K while Andepts had highest POMC and least exchangeable Al. Udults had most prominent increase in soil pH and reduction of exchangeable Al, indicating high response of the soil to application of water hyacinth compost. There was distinct correlation among most soil properties and sweet corn growth variables. The most prominent correlation among soil properties was observed between exchangeable Al and soil pH with coefficient correlation of – 0.91, followed by TSOC with MBC (r = 0.85). Plant height was pronouncedly related to shoot dry weight with coefficient correlation of 0.82. The distinct correlation of soil chemical property and sweet corn growth was found between soil available P, followed by TSOC and shoot dry weight with correlation 0.92 and 0.81, respectively. This indicates that soil available P has significant contribution on sweet corn growth.

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