Available at : https://ejournal.unib.ac.id/index.php/terrajournal ISSN 2621-0207
DOI : https://doi.org/10.31186/terra.2.1.1-8

TERRA
Journal of Land Restoration

Enhancing Soil Chemical Properties and Sweet Corn Growth by Solid Organic Amendments in Ultisol

Sri M. Sianturi[1], Zainal Muktamar[2], Mohammad Chozin[1]

[1]*Agronomy Department, University of Bengkulu*
[2]*Soil Science Department, University of Bengkulu (Corresponding author)*
e-mail: muktamar1959@yahoo.com

ABSTRACT

The negative impact of prolong and excessive application of synthetic fertilizers is a reason to reuse organic material as a plant nutrition resources and to enhance degraded soil. Organic materials such as animal and industrial wastes are commonly use as sources of organic amendment. The purpose of this study was to examine the changes in chemical properties of soil and the growth of sweet corn as affected by the application of solid organic fertilizers in Ultisol. This research was carried out in October 2016 until March 2017 at Greenhouse, University of Bengkulu, arranging in a Completely Randomized Design with two factors and three replications. The first factor was Organic amendment consisting of vermicompost, chicken manure, oil palm empty bunches compost (OPEBC). The second factors were rates of the amendment, i.e., 0, 10, 20, and 30 Mg ha^{-1}. Results indicate that total soil organic carbon (TSOC) and total soil nitrogen (TSN) were not considerably different among types of organic amendments used in this study; however, an increase in soil pH and a decline of exchangeable Al are highest in the application of OPEBC as compared to others. Likewise, the growth of sweet corn was the best in soil amended with chicken manure. Soil chemical properties such as TSOC, TSN, soil pH significantly enhanced but exchangeable Al markedly lowered up to 20 Mg ha^{-1}, then level off afterward. Sweet corn growth as indicated by plant height, shoot dry weight (SDW), and root dry weight (RDW) was also significant up to 20 Mg ha^{-1}. This study suggests that the addition of organic amendment at a rate of 20 Mg ha^{-1} is sufficient to provide plant nutrient and improvement of soil properties for sweet corn growth.

Keywords: organic amendment; sweet corn; Ultisol

INTRODUCTION

Low productivity of an Ultisol is mainly due to high saturation of aluminum (Al) in soil solution, causing Al toxicity of plant (Muktamar *et al.*, 1998; Fatmawaty & Firnia, 2010), low organic matter (Bertham, 2002) and low pH (Prasetyo & Suriadikarta, 2006), low available phosphorus (P) (Muktamar *et al*., 2016) due to the interaction of Al-P and/or Fe-P to form insoluble compound (Adams, 1980) as well as low plant nutrient (Prasetyo *et al*., 2005). The soil productivity has been commonly improved by application of synthetic agrochemicals. High input and long term use of the agrochemicals has led to significant reduction of soil fertility indicated by the shortage of nutrient availability and soil organic matter (Mariana *et al*., 2012), consequently, a drastic decrease in soil microorganism (Manuhutu *et al*., 2014).

The organic farming practice has been developed in the decades to be a solution of soil degradation since the practice improves soil properties from the exclusive application of organic amendment (Purnomo *et al*., 2014; Muktamar *et al*., 2017). Use of organic fertilizer increase availability of macro and micro plant nutrient as well as the formation of the humic metal complex (Barus, 2011; Spark, 2003) leading to alleviation of Al toxicity in the plant.

Nutrient content and properties of organic fertilizer are very diverse depending on its sources. Animal and industrial wastes are commonly used as sources of organic fertilizer. Vermicompost from animal waste is a soil amendment from organic decomposition using soil worms (Manshur, 2001). Vermicompost from dairy cattle contained 255.5 g kg^{-1} organic-C, 21.5 g kg^{-1} N, 2.4 g kg^{-1} P, and 5.5 g kg^{-1} K (Muktamar *et al*., 2017). Another vermicompost from coffee pulp content 146 g kg^{-1} organic –C, 16.6 g kg^{-1} N, 4.1 g kg^{-1} P, 7.0 g kg^{-1} K, 5.2 g kg^{-1} Ca, dan 3.1 g kg^{-1} Mg (Raphael & Velmourougane, 2011).

Compost from palm oil empty bunches is another solid organic fertilizer commonly used in the plantation to improve plant nutrient, consequently, reduces the use of synthetic fertilizer (Wardani, 2012). Ermadani *et al.* (2011) analyzed nutrient content of the amendment, containing 173.3 g kg^{-1} organic-C, 12.1 g kg^{-1} N, 7.6 g kg^{-1} P and 34.6 g kg^{-1} K. Chicken manure has also potential to improve soil productivity. The fertilizer contains 4.0 g kg^{-1} N, 2.0 0 g kg^{-1}P, and 15.0 0 g kg^{-1} K (Hartatik & Widiowati, 2013). The purpose of this study was to examine the changes in soil chemical properties and the growth of sweet corn as affected by the application of solid organic fertilizers in Ultisol.

MATERIAL AND METHOD

Experimental Design and Treatment

A greenhouse experiment was undertaken employing a completely randomized design (CRD) with two factors. The first factor was types of organic amendments, i.e., vermicompost, chicken manure, and oil palm empty bunch compost while the second factor was rates of solid organic amendment, i.e., control, 10, 20, and 30 Mg ha^{-1}. Each treatment was replicated three times, totaling 36 experimental units.

Media Preparation and Characterization

Soil sample at a depth of 0-20 cm was compositely collected from Faculty of Agriculture Experimental Station, the University of Bengkulu located in Kandang Limun Village, Bengkulu at 15 m above sea level. The soil order was an Ultisol with clay textural classification. The soil sample was air-dried, ground, and screened with 5 mm siever. The soil had 23 g kg^{-1} Total Soil Organic Carbon (TSOC), 1.82 g kg^{-1} Total Soil Nitrogen (TSN), 7.77 mg kg^{-1} available P, 4.08 cmol kg^{-1} exchangeable Al, and soil pH of 4.9.

Vermicompost was collected from Closed Agricultural Production System Research Station located in Air Duku Village. The amendment contained 5.6% organic carbon, 2.12% N, 0.41% P and pH of 5.8. Chicken manure was purchased from a local chicken farm. The manure had 8.69% organic carbon, 1.54% N, 0.74% P and pH of 6.0. Oil palm empty bunch compost was from Oil Palm Plantation of PT Bio Nusantara located in Central Bengkulu District. The nutrient content of the compost was 6.82% organic carbon, 1.22% N, 0.54% P, and a pH of 6.5.

Ten kg of soil sample was incorporated with solid organic amendment according to each treatment and placed in 10 kg polybag. The soil was incubated for a week before sweet corn planting. Polybags was randomly placed in a wooden stand in the Green House. During the incubation, the soil was retained moist by watering when necessary.

Sweet Corn Cultivation

After a week of cropping media incubation, two sweet corn seeds were placed in holes in the center of polybag. Thinning was completed a week after planting by leaving the healthy one. The plant did not receive additional synthetic fertilizer during the period of the growth stages. The plant was watered frequently to prevent water shortage for its growth.

The experiment was ended at the maximum growth stages indicated by tassel emergence. The plant was cut at the bottom, washed with water, oven dried at 70 ^{o}C and weighed for shoot dry weight. Sweet corn roots were carefully separated from the soil, washed with water, dried on the oven at a temperature of 70 ^{o}C, weight for root dry weight. One kg of soil was sampled, air-dried, ground, sieved with a 0.5 mm siever and examined for soil chemical properties. Total soil organic carbon was analyzed using Walky and Black Method, TSN with Kjeldahl Method, available P using Bray I Method, exchangeable Al with Titrimetric Method after extraction using 1 N KCl, and soil pH using Electrometric Method at the ratio 1:1 of soil and distilled water.

Statistical Analysis

Data were evaluated for ANOVA using CoStat 6.4. at a confidence level of 95%. Treatment means for types of the solid organic amendment were separated using Duncan Multiple Range Test (DMRT) at a probability level of 5% while the rate of the amendment using polynomial orthogonal.

RESULT AND DISCUSSION

Collected data were subjected to Analysis of variance at a probability level of 5%. Results of the experiment show that type of organic amendment has a significant effect on soil pH, exchangeable Al, available P, plant height, SDW, and RDW even though it does not affect TSOC and TSN. Likewise, the rates of organic amendment provide a significant influence on all variables observed in this experiment.

For all soil and plant variables, no interaction between type and rate of organic amendments was observed but available P.

Soil Chemical Properties

Organic carbon content is a good indicator of soil quality since it is a functional fragment of the soil organic matter. Productive soil is typically indicated by the high content of soil organic matter. Soil organic carbon content ranges from 4.56 to 9.12% is reflected in the good quality and productive soil (Lal, 1994) so that it is able to supply nutrients for plant and microorganism in the soil. Organic matter addition is necessary to preserve and increase organic carbon content in soil (Syukur, 2005; Syukur & Harsono, 2008). Characteristically, Ultisol has low organic matter due to prolong and intensive soil development. In this study, addition of organic amendment does not provide an increase in TSOC (Table 1), possibly due to that soil organic matter content at a specific moment is dependent on equilibration among number of factors such as addition and loss of soil organic matter such as decomposition and leaching (Wander *et al*., 1994).

Table 1 also shows that the application of different types of the organic amendment does not provide different content of soil organic carbon. Nariratih *et al*. (2013) also designate a similar result where an application of chicken manure, paddy straw compost, and cacao peel compost did not provide a significant increase on soil organic carbon, meaning that the three types of solid organic fertilizers had the same contribution.

Table 1. Selected soil chemical characteristics under types of organic amendment

Organic Amendment	TSOC ($g\ kg^{-1}$)	TSN ($g\ kg^{-1}$)	Exch Al ($cmol\ kg^{-1}$)	Soil pH
Vermicompost	24.26 a	2.43 a	3.71 a	5.11 a
Chicken Manure	25.04 a	2.46 a	3.62 a	5.12 a
OPEBC	22.85 a	2.38 a	2.43 b	5.36 b

Treatment means at the same column followed by the same letter are not significantly different. TSOC = Total soil organic carbon; TSN = Total soil nitrogen; OPEBC = Oil palm empty bunch compost.

A similar trend to TSOC is shown in total soil nitrogen where the addition of different organic amendment does not exhibit significant differences in TSN as presented in Table 1. A similar study conducted by Bahri *et al*. (2016) showed that fertilization with chicken manure exhibited significant higher yield than biochar but soil nitrogen. A different result was concluded by Nariratih *et al.* (2013) where the application of chicken manure showed higher TSN than the other composts. All types of organic fertilizers tended to contribute the same amount of nitrogen to the soil. A slight increase in TSN is observed when it is compared to that its initial content. On average, TSN increases by more than 33% in comparison to that of initial content.

Even though TSOC is similar among types of organic amendment, exchangeable Al is significantly different as shown in Table 1. Exchangeable Al from soil treated with oil palm empty bunch compost is lowest as compared to that of other organic amendments. This result may have been associated with the different kinds of functional groups in humic and fulvic acids from the organic fertilizers. Decomposition of organic matter also liberates humic and fulvic acids with diverse amount of functional groups (Spark, 2003) binding to Al forming stable Al organo-complex (Muktamar *et al*., 1998; Ifansyah, 2013).

The opposite trend from exchangeable Al is observed in soil pH where oil palm empty bunch compost has the highest soil pH in comparison to the other organic amendments (Table 1). Formation of Al organo-complex lowers hydrogen production from Al hydrolysis; consequently, soil pH rises significantly. The similar result was noted by Anggi *et al*. (2018) where an application of a different animal source of liquid organic fertilizer had considerable differences of soil pH, showing that lowest pH at low concentration was soil treated with LOF from rabbit wastes, but the opposite is true at high concentration.

Independently, rates of solid organic amendments exhibit a considerable effect on soil chemical properties observed in this study. A substantial increase in TSOC is observed between control and the rate of 20 $Mg\ ha^{-1}$, afterward, leveling off until the rate of 30 $Mg\ ha^{-1}$ (Figure 1) as indicated by no significant difference of TSOC between a rate of 20 and 30 $Mg\ ha^{-1}$. Soil organic content at the rate of 20 $Mg\ ha^{-1}$ is 96.75% higher than that of control. A comparable study by Elfayetti (2017) concluded that application of vermicompost at the rate of 20 $Mg\ ha^{-1}$ had 87.4% soil organic matter greater than without addition. Syukur & Indah (2006) also confirmed that cattle manure at the rates of 10, 20, and 40 $Mg\ ha^{-1}$ increased TSOC by 12.5%, 20.5%, and 25.51%, respectively, as compared to control. Escalation of TSOC will contribute to the improvement of nutrient availability during the decomposition of soil organic matter.

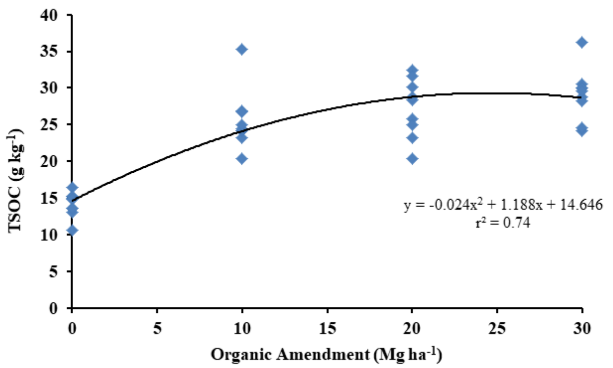

Figure 1. Total soil organic carbon under different rates of solid organic fertilizer

Similar fashion to TSOC, it is observed that TSN enhances profoundly to the rate of 20 Mg ha^{-1}, but the increment reduces afterward (Figure 2). Nitrogen availability in soil is prominently dependent on soil organic matter content, and its mineralization consequently increases TSN (Cookson *et al.*, 2005). The rate of organic N conversion to inorganic N to which enzyme has involved hydrolyzing protein complex is a factor in the availability N in soil (Benbi & Richter, 2002). Soil amended with a solid organic fertilizer at a rate of 20 Mg ha^{-1} had 2.3 fold higher TSN than control. A comparable result was suggested by Sihite *et al.* (2016) where the application of chicken manure 120 g polybag^{-1} was able to increase TSN by 0.2% in comparison to control.

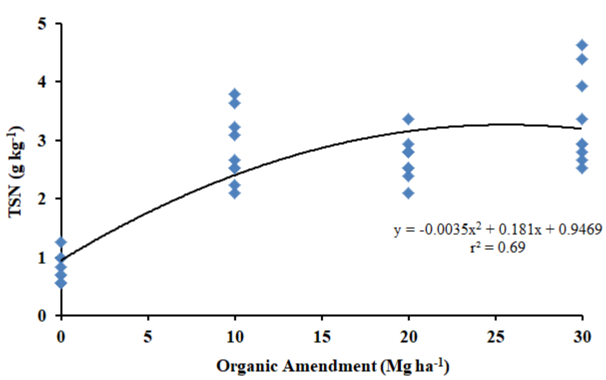

Figure 2. Total soil nitrogen as affected by the organic amendment

Under the acid condition, organic matter has a significant effect on total acidity mainly aluminum saturation in the soil solution. The higher rate of soil organic amendment markedly lowers exchangeable Al up to a rate of 20 Mg ha^{-1}, then, leveling off afterward, indicated by no significantly different from that of 30 Mg ha^{-1} (Figure 3). Soil organic matter decomposition also releases organic acids, such as humic and fulvic acids, containing a large number of functional groups mainly carboxyl and phenolic. These functional groups bind metal such as Al, forming an organo-metal complex (Muktamar *et al.*, 1998; Spark, 2003; Firda *et al.*, 2017), leading to lowering exchangeable Al in the soil. Exchangeable Al reduces by 83% by application of solid organic amendment at 20 Mg ha^{-1} as compared to control. This result is an agreement with that carried out by Ifansyah (2013) who concluded that the addition of humic acid lowered exchangeable Al and Fe in the soil. Another study by Muktamar *et al.* (2016) showed that solid organic fertilizer from water hyacinth at a rate of 25 Mg ha^{-1}is able to reduce exchangeable Al more than 270% as compared to control.

Reduction of exchangeable Al is followed by an increase in soil pH as indicated in Figure 4. Formation of Al-organo complex considerably lessens Al hydrolysis in the soil, consequently lowers hydrogen production (Mukhlis *et al.*, 2011), resulting in a rise in soil pH. As in other cases, the amendment has significant increase up to 20 Mg ha^{-1}, then leveling off (Figure 4), indicated by no significant difference of soil pH in the application of 20 and 30 Mg ha^{-1}. Soil pH rises by nearly 15% in soil fertilized with 20 Mg ha^{-1} in comparison to that of control. Using water hyacinth compost, Muktamar *et al.* (2016) confirmed that the compost addition increased soil pH from 4.35 at control to 5.6 at 25 Mg ha^{-1}. Another study by Anggita *et al.* (2018) concluded that application of liquid organic fertilizer from rabbit, goat, and cattle wastes considerably increased soil pH of an Ultisol.

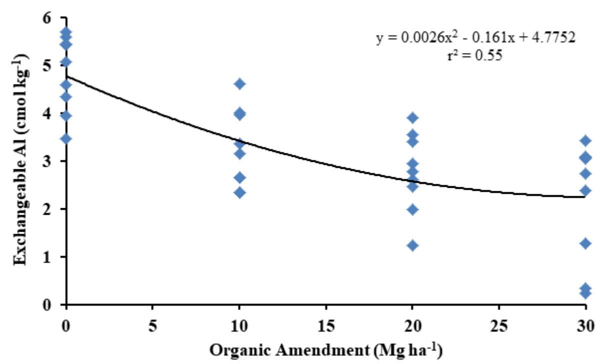

Figure 3. Exchangeable Al as influenced by solid organic amendment

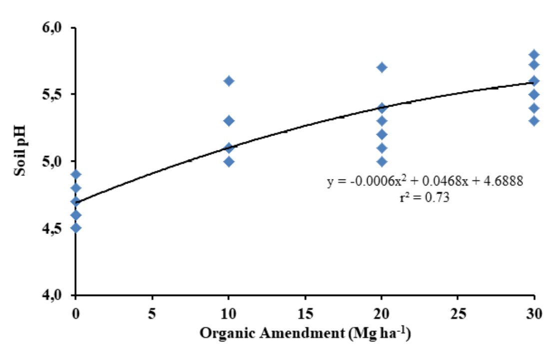

Figure 4. Soil pH under different rates of organic amendment

Application of solid organic amendment has marked effect on available P in soil. Chicken manure provides the greatest soil available P, followed by oil palm empty bunches compost and vermicompost (Figure 5). Likewise, chicken manure provides the fastest available P to the soil, indicated by the slope of the regression line. Increase in soil available P may have been associated with the released P from soil amendment as well as to the release of P from aluminum and iron phosphates. Functional groups resulting from organic matter decomposition compete with the phosphates, leading to the release of P to the soil solution. A study by Muktamar *et al.* (2018) indicated similar result where the application of vermicompost up to 30 Mg ha^{-1}, considerably enhanced the availability of P in soil and the effect lasted up to the second planting.

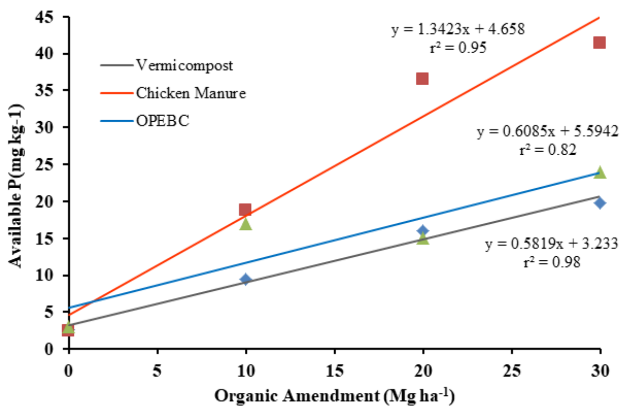

Figure 5. Soil available P at different types of organic amendments

Sweet Corn Growth

Improvement of soil chemical properties has a significant effect on the growth of sweet corn. This study reveals that different types of organic amendments provide a different effect on plant height of sweet corn (Table 2). The tallest sweet corn is achieved by application of oil palm empty bunches compost (OPEBC), followed by those of chicken manure and vermicompost even though N content at the end of the study is not different among types of organic amendments. This result may have been associated with the speed of the organic matter decomposition from the sources. Widowati *et al.* (2004) noted that chicken manure decomposed faster and contained higher available nutrients than rice husk and cacao bark composts.

Table 2. Sweet corn growth under different types of amendments

Organic Amendment	PH (cm)	SDW (g lant^{-1})	RDW (g lant^{-1})
Vermicompost	95.2 a	12.2 a	1.4 a
Chicken Manure	116.4 b	22.7 b	2.3 b
OPEBC	113.1 b	17.0 a	1.9 ab

Treatment means at the same column followed by the same letter are not significantly different PH=Plant height; SDW=Shoot dry weight; RDW=Root dry weight; OPEBC=Oil palm empty bunch compost.

As in the case of plant height, the study indicates that types of amendments provide significant differences in shoot dry weight of sweet corn (Table 2). Sweet corn fertilized with chicken manure has greatest shoot dry weight followed by those of OPEBC and vermicompost. Application of chicken manure has 33.5% and 86.1% higher SDW as compared to OPEBC and vermicompost, respectively. A similar trend to SDW, root dry weight (RDW) is highest in the application of chicken manure, followed by OPEBC and vermicompost (Table 2). Chicken manure fertilization exhibits 63.3% and 23.4% higher RDW in comparison to those of OPEBC and vermicompost, respectively. The dry weight of biomass is highly dependent on the availability of nutrients and the rate of photosynthesis and respiration processes in the plant; consequently, dry biomass acquires higher, designating vegetative growth well proceeded.

Application of organic amendment up to 20 Mg ha^{-1} escalates sweet corn growth, afterward; the increase lessens (Figure 6). Increasing fertilization rate to 20 Mg ha^{-1}, plant height increases by more than double as compared to the control. No fertilization brought about a severe deficiency of nutrients, leading to poor sweet corn growth. A similar result was found by Simanjuntak *et al.* (2016) where organic fertilizer at the rate of 22.5 Mg ha^{-1} linearly enhanced plant height of maize. The release of N during organic matter decomposition is available to the plant, producing protein for tallying the height (Syarif, 1985).

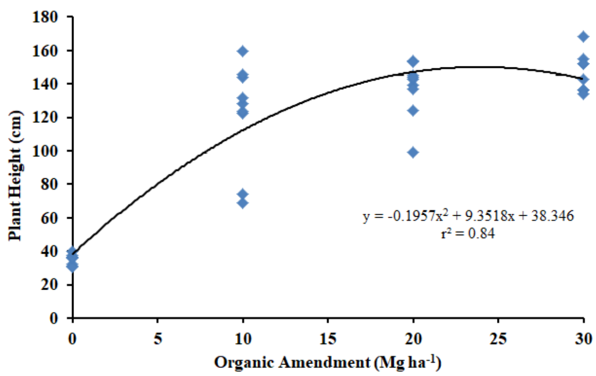

Figure 6. Sweet corn height as a function of the rates of organic amendment

Application of organic amendment provides a marked increase in SDW as indicated in Figure 7. Shoot dry weight escalates by more than 53 folds 20 Mg ha^{-1} in comparison to that control, afterward, an increase lessens. Availability of plant nutrients from organic matter decomposition such N (Figure 2) and P (Figure 5) as well improvement of soil as indicated by higher soil pH (Figure 4) and reduction of Al (Figure 3) contributes to the enhancement of sweet corn growth; consequently, there is a significant increase in SDW. This result is in accordance to that concluded by several researchers where the application of soil organic fertilizer profoundly increased plant shoot dry weight (Muktamar *et al.*, 2016; Sudartiningsih *et al.* (2002); Hasibuan *et al.*, 2014; Muktamar *et al.*, 2017).

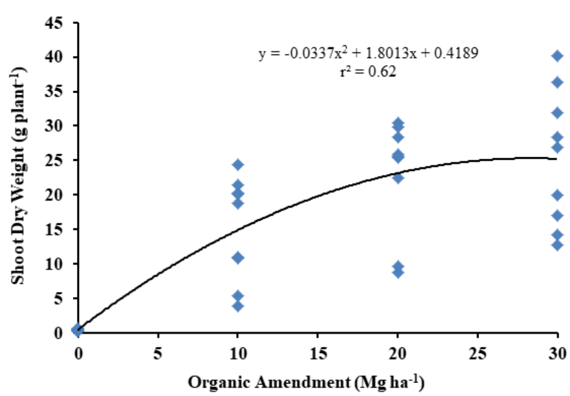

Figure 7. The effect of the organic amendment on shoot dry weight of sweet corn

Similar fashion to SDW, significant increase in root dry weight (RDW) is also observed up to 20 Mg ha^{-1} as seen in Figure 8, then leveling off afterward. Root dry weight increases by almost 16 folds when sweet corn was amended with 20 Mg ha^{-1} as compared to without amendment. This result might have been associated with the increase in available nutrients releasing form organic decomposition and improvement of soil properties. A study by Simanjuntak *et al.* (2016) reported a similar result where the application of chicken manure at a rate of 22.5 Mg ha^{-1} is able to improve root growth as indicated by its root dry weight.

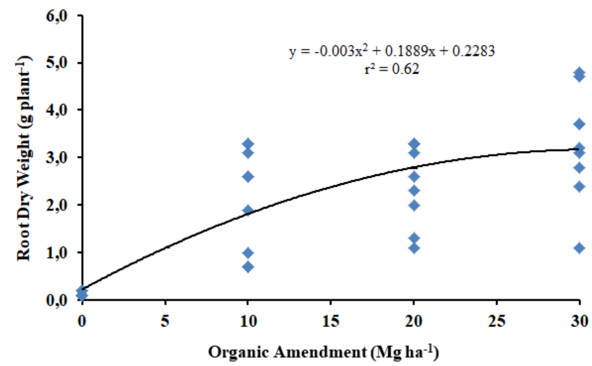

Figure 8. Root dry weight of sweet corn as a function of organic amendment

CONCLUSION

Application of 3 types of organic amendments on Ultisol does not provide differences in total soil organic carbon and total soil nitrogen. However, the use of oil palm empty bunches compost (OPEBC) has the highest soil pH as well as lowest exchangeable Al as compared to chicken manure and vermicompost. Likewise, available P linearly increases with rates of the organic amendment, but the increment is highest on chicken manure in comparison to OPEBC and vermicompost. Sweet corn growth is the greatest on the application of chicken manure as designated by plant height, shoot dry weight and root dry weight.

Total soil organic carbon, total soil nitrogen, and soil pH considerably increases and exchangeable Al markedly lowers as the rate of organic amendment rises to 20 Mg ha^{-1}, then leveling off afterward, indicated by no significant difference with those at the rate of 30 Mg ha^{-1}. The better soil chemical properties brings about the enhancement of sweet corn growth as shown in plant height, shoot dry weight and root dry weight. As in the case of soil properties, the improvement of sweet corn growth is significant up 20 Mg ha^{-1}. The study suggests that the addition of organic amendment at a rate of 20 Mg ha^{-1} is sufficient to provide an improvement of nutrient availability, consequently sweet corn growth.

References

Adams, F. (1980). Interaction of Phosphorus with Other Elements in Soils and in Plants *in The Role of Phosphorus in Agriculture*. Khasawneh, F.E., Sample E.C. & Kamprath, E. J. pp 655-674. ASA. Wisconsin.

Anggita, T., Muktamar, Z. & Fahrurrozi, F. (2018). Improvement of selected Soil chemical properties and potassium uptake by mung beans after application of liquid organic fertilizer in Ultisol. *Terra Journal of Land Restoration*, 1(1), 1-7.

Bahri, S., Budianta, D. & Munandar, M. (2016). Perubahan karakteristik beberapa sifat kimia tanah dengan pemberian biochar dan pupuk kandang ayam pada tanah Ultisol. *Klorofil: Jurnal Penelitian Ilmu-Ilmu Pertanian*, 11(2), 77-84.(in Indonesian).

Barus, J. (2011). Uji efektivitas kompos jerami dan pupuk NPK terhadap hasil padi. *J. Agrivigor,* 10(3), 247-252. (in Indonesian).

Benbi, D.K, & Richter, J. (2002). Critical review of some approaches to modelling nitrogen mineralization. *Biol Fertil Soils,* 35, 168–183.

Bertham, Y. H. (2002). Respon tanaman kedelai (*Glycine max* (L) Merill) terhadap pemupukan fosfor dan kompos jerami pada tanah ultisol. *J Ilmu Pertan Indonesia*, 4(2), 78-83. (in Indonesian).

Cookson, W. R., Cornforth, I. S. & Rowarth, J. S. (2002). Winter soil temperatur (215 ^{0}C) effect on nitrogen transformations in clover green manure amandend and unamandend soils : a laboratory and field study. *Soil Biol. Biochem*, 34, 1401-1415.

Elfayetti, E. (2017). Pengaruh pemberian kascing dan pupuk N, P, K buatan pada Ultisol terhadap sifat kimia tanah dan hasil tanaman jagung (*Zea mays* L.). *J. Geografi*, 1(1), 51-56. (in Indonesian)

Ermadani, Mazur, A. & Mahhub, I. A. (2011). Pengaruh residu kompos tandan buah kosong kelapa sawit terhadap beberapa sifat kimia ultisol dan hasil kedelai. *Jurnal Penelitian Universitas Jambi Seri Sains*, 13(2), 11-18.

Fatmawaty. A. A. & Firnia, D. (2010). Studi pengaruh intensitas pengolahan tanah dan pemberian pupuk organik terhadap sifat fisik kimia tanah dan hasil tanaman jagung (*Zea mays sacharata* Sturt) pada tanah Ultisol Banten. *Prosiding Semirata Bidang Ilmu-Ilmu Pertanian BKS-PTN Wilayah Barat. Fakultas Pertanian Universitas Bengkulu*. pp. 461-467.

Firda, F., Mulyani, O. & Yuniarti, A. (2017). Pembentukan, karakterisasi serta manfaat asam humat terhadap adsorbsi logam berat. *SoilREns*, 14(2), 9-13. (in Indonesian)

Hartatik, W. & Widiowati, L. R. (2013). Pupuk Kandang. *In : Pupuk Organik dan Pupuk Hayati*. Balittanah, Bogor. pp. 59 – 82.

Hasibuan, S. Y., Damanik, M. M. B. & Sitanggang, G. (2014). Aplikasi pupuk SP-36 dan pupuk kandang ayam terhadap ketersediaan dan serapan fosfor serta pertumbuhan tanaman jagung pada Ultisol Kwala Bekala. *J. Agroekoteknologi*, *2*(3), 870-875.

Ifansyah, H. (2013). Soil pH and solubility of aluminum, iron, and phosphorus in Ultisol: the roles of humic acid. *J. Trop. Soil,* 18(3), 203-208.

Lal, R. (1994). Method and Guidelines for Assessing Sustainable Use for Soil and Water Resources in the Tropics. SMSS Tech. Monograph no. 21. USDA.

Manuhutu A. P., Rehatta, H. & Kailola, J. J. G. (2014). Pengaruh konsentrasi pupuk hayati bioboost terhadap peningkatan produksi tanaman selada (*Lactuca sativa*. L.). *Agrologia*, 3 (1), 18-27. (in Indonesian).

Manshur. (2001). Vermikompos (kompos cacing tanah) dan pupuk organik yang ramah lingkungan. *Instalansi Penelitian dan Pengkajian Teknologi Pertanian (IPPTP)* Mataram. (in Indonesian).

Mariana, P., Sipayung, R. & Sinuraya, M. (2012). Pertumbuhan dan produksi bawang merah (*Allium ascalonicum* L.) dengan pemberian vermikompos dan urine domba. *J. Agroekoteknologi*, 1(1), 124-138. (in Indonesian).

Mukhlis, Sariffudin & Hanum, H. (2011). Kimia Tanah. Teori dan Aplikasi. USU Press, Medan. (in Indonesian).

Muktamar Z., Aneri, D. & Suprapto. (1998). Penurunan Aluminium teradsorpsi pada tanah asam sitrat dan oksalat. *J. Penelitian UNIB* 11, 1-4. (in Indonesian).

Muktamar, Z., Justisia, B. & Setyowati, N. (2016). Quality enhancement of humid tropical soils after application of water hyacinth (*Eichhornia crassipes*) compost. *Journal of Agricultural Technology* 12(7.1), 1211-1228.

Muktamar, Z., Sudjatmiko, S., Chozin, M., Setyowati, N. & Fahrurrozi. (2017). Sweet corn performance and its major nutrient uptake following application of vermicompost supplemented with liquid organic fertilizer. *International Journal on Advance Sci. Engineering Information Technology*, 7 (2), 602-608.

Muktamar Z., Sudjatmiko, S., Fahrurrozi, F., Setyowati, N. & Chozin, M. (2017). Soil chemical improvement under application of liquid organic fertilizer in closed agriculture system. *International Journal of Agricultural Technology,* 13(7.2), 1715-1727.

Muktamar, Z., Adiprasetyo, T., Yulia, Suprapto, Sari, L., Fahrurrozi, F. & Setyowati, N. (2018). Residual effect of vermicompost on sweet corn growth and selected chemical properties of soils from different organic farming practices. *International Journal of Agricultural Technology,* 14 (7), 1471-1482.

Nariratih, I., Damanik, M. M. B. & Sitanggang, G. S. G. (2013). Ketersediaan nitrogen pada tiga jenis tanah akibat pemberian tiga bahan organik dan serapannya pada tanaman jagung. *J. Agroekoteknologi*, 1(3), 479-488. (in Indonesian).

Prasetyo B. H., Subardja, D. & Kaslan, B. (2005). Ultisols dari bahan volkan andesitik di lereng bawah G. Ungaran. *Jurnal Tanah dan Iklim,* 23, 1-12. (in Indonesian).

Prasetyo, B.H. & Suriadikarta, D. A. (2006). Karakteristik, potensi dan teknologi pengelolaan tanah Ultisol untuk pengembangan pertanian lahan kering di Indonesia. *Litbang Pertanian*, 25(2), 39-47. (in Indonesian).

Raphael, K. & Velmourougane, K. (2011). Chemical and microbiological changes during vermicomposting of coffee pulp using exotic (*Eudrilus eugeniae*) and native earthworm (*Perionyx ceyanesis*) Species. *Biodegradation,* 22, 497-507.

Sihite, E. A., Damanik, M. M. B. & Sembiring, M. (2016). Perubahan beberapa sifat kimia tanah, serapan P dan pertumbuhan tanaman jagung pada tanah Inceptisol Kwala Bekala akibat pemberian pupuk kandang ayam dan beberapa sumber P. *J. Agroekoteknologi*, 4(3), 2082-2090. (in Indonesian).

Simanjuntak, D., Damanik, M. M. & Sitorus, B. (2016). Pengaruh tepung cangkang telur dan pupuk kandang ayam terhadap pH, ketersediaan hara P dan Ca tanah Inseptisol dan serapan P dan Ca pada tanaman jagung (*Zea mays* .L). J. *Agroekoteknologi*, 4(3), 2139-2145. (in Indonesian).

Spark, D. (2003*). Environmental Soil Chemistry*. 2nd ed. Academic Press., London

Sudartiningsih, D., Utami, S. R. & Prasetya, B. (2002). Pengaruh pemberian pupuk urea dan pupuk "organik diperkaya" terhadap ketersediaan dan serapan N serta produksi cabai besar (*Capsicum annum* L.) pada Inceptisol Karang Ploso Malang. *Jurnal Agrivita*, 24(1), 63-69. (in Indonesian).

Syarief. (1985). *Kesuburan dan Pemupukan Tanah Pertanian*. Pustaka Buana. Bandung. (in Indonesian).

Syukur, A. (2005). Penyerapan posfor oleh tanaman jagung di tanah pasir pantai bugel dalam kaitannya dengan tingkat frekuensi penyiraman dan pemberian bahan organik. *Jurnal Ilmu Tanah dan Lingkungan,* 5(2), 20-26. (in Indonesian).

Syukur, A. & Indah, N. M. (2006). Kajian pengaruh pemberian pupuk organik terhadap pertumbuhan dan hasil tanaman jahe di Inceptisol, Karanganyar. *Jurnal Ilmu Tanah dan Lingkungan*, *6*(2), 124-131. (in Indonesian).

Syukur, A. & Harsono, E. S. (2008). Pengaruh pemberian pupuk kandang dan NPK terhadap beberapa sifat kimia dan fisika tanah pasir Pantai Samas Bantul. *Jurnal Ilmu Tanah dan Lingkungan*, 8(2), 138-145. (in Indonesian).

Wander, M. M., Traina, S. J., Stinner, B. R. & Peters, S. E. (1994). Organic and conventional management effects on biologically active soil organic matter pools. *Soil. Sci. Soc. Am. J.*, 58, 1130-1139.

Wardani, D. E. (2012). Tandan kosong kelapa sawit (TKKS) sebagai alternatif pupuk organik. *http://www.priodicalonline.ac.id.* (downloaded 27 March 2016). (in Indonesian).

Widowati. L. R., Widati, S., Jaenudin, U. & Hartatik, W. (2004). Pengaruh pupuk kompos organik yang diperkaya dengan bahan mineral dan pupuk hayati terhadap sifat-sifat tanah, serapan hara dan produksi sayuran organik. Laporan Proyek Penelitian Program Pengembangan Agribisnis Balai Penelitian Tanah, Bogor. (in Indonesian).