Research article

Accumulation of Copper in Kale (*Brassica alboglabra*) and Soil Fertilized with Swine Manure, Compost and Vermicompost under Different Thai Soil Series

ARPHORN THONGBURAN
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand
Email: p_arphorn@yahoo.com

CHULEEMAS BOONTHAI IWAI*
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand
Email: chuleemas1@gmail.com

Received 8 February 2018 Accepted 20 May 2018 (*Corresponding Author)

Abstract The aim of the study was to evaluate the variation in the copper (Cu) accumulation in kale and two different Thai soil series (Korat and Nampong soil series) treated with swine manure, compost and vermicompost. Completely randomized design (CRD) experiment was conducted on the soil samples collected from Korat and Nampong soil series. Same amount of treatments namely swine manure, compost and vermicompost of 18.75 t/ha were applied in each experimental unit and harvested after 45 days. Results showed that the accumulation of Cu in roots and shoots were found higher in Nampong soil series than Korat soil series. The Cu accumulation in roots and shoots was highest when treated with swine manure. The Cu content in roots and shoots were 6.62 and 3.69 mgkg^{-1} respectively. However, there was no significant difference in the Cu content when treated with compost and vermicompost. The Cu accumulation in Korat soil series was found higher than Nampong soil series at 6.29 and 6.19 mgkg^{-1} respectively when treated with swine manure. However, accumulation of Cu in Kale and soil depend on difference in soil texture and speciation of Cu in swine manure, compost and vermicompost. This is because Korat soil contains clay mineral which absorbs Cu whereas Nampong soil series is more of sandy which absorbs less Cu.

Keywords swine manure, compost, vermicomposting, Nampong soil series, Korat soil series

INTRODUCTION

Fertilization of crops with swine manure is a common practice throughout the world. Due to the relatively high Cu contents in swine manure, continuous application of swine manure could have negative effects on soil and plant. Cu is nutrient for plant growth and development, Cu may become phytotoxic and cause metabolic disorders at high soil concentrations, and lead to a potential threat to human health through the food chain (Xu et al., 2013). The increase of Cu in human body causes some major diseases such as brain, skin, pancreas, and heart diseases (Nurdan and Okan, 2013). The bioavailability and toxicity of metals in soil can vary over several orders of magnitude depending on soil modifying factors. The effect of soil types on the bioavailability and toxicity of metals to soil organism has been studies (Olugbenga et al., 2010). Clay minerals are generally regarded as important natural ion exchange materials because they are generally coated with metal oxide and organic matter. Clay has small particle size and a large surface area per unit weight, these properties is believed to be a good adsorbent for heavy metal (Sajidu et al., 2006). Many researchers studied heavy metal uptake and transports within the plants and accumulation of Cu in soil. But the most of widely studies with different kind of plant, raw material and soils.

OBJECTIVE

The aim of this study was to evaluate the accumulation of copper in kale planted in two different soil series (Korat and Nampong soil series) that treated with swine manure, compost and vermicompost.

METHODOLOGY

Soil Sample Collection and Preparation

The soil used in this study came from Northeast of Thailand were collect from Korat and Nampong soil series. Soil was sample from 0-15 cm. depth, air-dried at ambient temperature and finally, sieved to < 2 mm. used for pot experiment and for measurement of the soil's physical-chemical properties.

Soil pH and electrical conductivity (EC) were measured in a 1:5 soil/water mixture, organic matter was determined by the Walkley-Black (Walkley and Black, 1965), particle-size distribution (clay, silt and sand content) was determined by Hydrometer method, cation exchange capacity (CEC) was measured by the ammonium acetate saturation method (Bremner, 1965) and determined of Cu in the soil extraction with DTPA measured by Atomic absorption spectrophotometer.

Composting and Vermicomposting Preparation

Compost and vermicompost were pepared with swine manure, cassava peel, rice husk ash and soil in propotion ration 2:6:1:1 and earthworm species (*Eudrillus eugeniae*) was introduced to the substrate for vermicomposting with the moisture content 80 to 90%. After 60 days separate earthworm and air-dried at ambient temperature for compost and vermicompost, finally sieved to < 2 mm. used for pot experiment and for measurement chemical properties.

Analysis chemical property of compost and vermicompost; pH and electrical conductivity (EC) were measured in a 1:10 mixture with water, organic matter was determined by the Walkley-Black (Walkley and Black, 1965), Total nitrogen was determined by the Kejldahl method, Total phosphorus, Potassium and Cu digested with mixture of HNO_3: $HClO_4$ (1:1) followed by standard method (AOAC, 2000).

The sequential extraction of speciation of Cu in swine manure, compost and vermicompost following five fraction were exchangeable, bound of carbonate, bound of iron and manganese oxide, bound of organic matter and residual (Tessier, 1979).

Pot Experiment

Plastic pots were filled with 1 kg of air-dried soil sieved to <2 mm. (Ruiz et al., 2009) Four different experiment series were; control soil without swine manure, compost and vermicompost, soil with swine manure, soil with compost and soil with vermicompost under Korat and Nampong soil series. Each series consisted of three replicate in CRD experiment.

Kale (*Brassica alboglabra)* seed were sown 10 seeds per pot. After 10 days subsequently reduced to 3 seeds per pot. Same amount of treatments namely swine manure, compost and vermicompost of 18.75 t/ha were applied in each experimental unit and harvested after 45 days. Plant shoots and root were thoroughly washed with de-ionize water, weighed, stored at 75 ºC, finely ground to fine powder and sealed in plastic bags for subsequent Cu analysis. The dry plants were digested using mixture of HNO_3: $HClO_4$ (1:1) followed by standard method (AOAC, 2000) The total metal accumulation rate (TMAR) in K ale was calculate using the following equation.

$$TMAR = [(M_{root} \text{ x } DW_{root}) + (M_{shoot} \text{ x } DW_{shoot})] / (DW_{root} + DW_{shoot})$$

Where M_{shoot} and M_{root} represent the total Cu concentration in Kale shoot and root (mgkg^{-1}), respectively, while DW_{root} and DW_{shoot} represent the weight of Kale roots and shoots (g.) respectively. (Ruiz et al., 2009).

Statistical Analysis

The Statistic 10 software (version 10, USA) was used to analyze the data including the analysis of variance (One Way ANOVA). Treatment means were compared using least significance difference (LSD) at $P< 0.05$.

RESULTS AND DISCUSSION

Material Characterization

The main physical-chemical property of the soil (Korat and Nampong soil series) were analyzed and classified as loam and loamy sand include clay content at 16.61 and 6.46% respectively (Table 1).

Table 1 Physical-chemical property of the soil used for experiment

Soil properties	Korat soil series	Nampong soil series
1. pH (1:5)	6.42	6.79
2. EC (1:5; ds/m)	0.04	0.03
3. CEC (cmol/kg)	7.93	3.38
4. Organic Matter (%)	1.59	0.97
5. Total Nitrogen (%)	0.08	0.03
6. Available Phosphate (%)	49	53
7. Exchangeable Potash (%)	33	29
8. Copper (Cu; mg/kg)	0.83	0.26
9. Texture	Loam	Loamy sand
Sand (%)	50.94	78.87
Silt (%)	32.45	14.67
Clay (%)	16.61	6.46

Table 2 Chemical-property of the swine manure, compost and vermicomost used for experiment

Property	Swine manure	Compost	Vermicompost
1. pH (1:10)	7.4	7.94	7.46
2. EC (1:10; ds/m)	2.2	1.013	1.223
3. Total Nitrogen (%)	2.3	0.63	0.54
4. Total Phosphate (%)	9.4	1.10	1.32
5. Total Potash (%)	1.3	0.78	1.00
6. Organic Matter (%)	52.7	19.8	15.9
7. Copper (Cu; mg/kg)	731.7	175.5	209.1

The swine manure, compost and vermicomost used for experiment were analyzed chemical properties (Table 2). Contamination of Cu in swine manure has been found in high concentration because Cu is added to feed additive for pig growth promoting.

Speciation of Cu in swine manure, compost and vermicompost as show in Fig. 1, the swine manure has high concentration of Cu in exchangeable fraction. But compost and vermicomposting process cloud reduced the exchangeable form and changed to bound of organic matter.

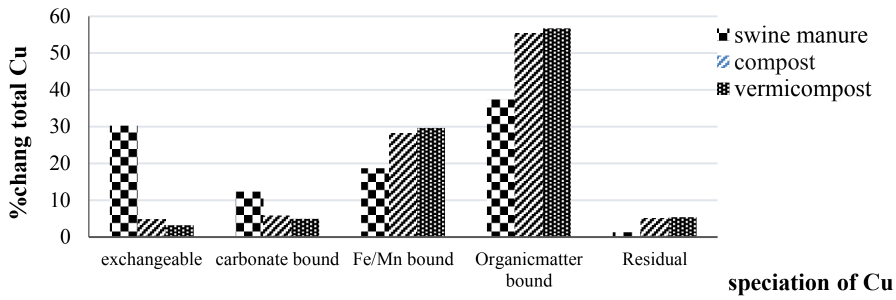

Fig. 1 Speciation of Cu in swine manure, compost and vermicompost

Effect of Swine Manure, Compost and Vermicompost on Accumulation of Cu in Kale and Soils

The total metal accumulation rate (TMAR), shoot and root Cu concentration for Kale are presented in Table 3. The result show that the treatment with swine manure significantly increased the TMAR of Cu. This is a direct consequence of the observed increase in the Cu root concentration **(**Ruiz et al**.**,2009**).** The accumulation of Cu in roots and shoots were found higher in Korat soil series than Nampong soil series. The Cu accumulation in roots and shoots was highest when treated with swine manure. The Cu content in roots and shoots were 6.62 and 3.69 mg/kg respectively. However there was no significant difference in the Cu content when treated with compost and vermicompost. The accumulation of metal concentration in root and shoot was only observed for the most mobile metal. The nutrients with lower mobility are mainly accumulated in the roots, while those with relatively higher mobility are accumulated in the shoots to greater extent (Materechera, 2002). From the roots, transition metals are mainly transported to the shoot via the xylem. Chelation of metals with certain intracellular chelators, e.g. histidine, nicotianamide and citrate, appears as a key process that protes root-to-shoot mobility of a metal via xylem transport (Clemens et al., 2002).

Table 3 Effect of swine manure, compost and vermicompost on shoots, root and total accumulation of Cu (mgkg^{-1}) in Kale

Treatment	Korat soil series			Nampong soil series		
	shoot	root	TMAR	shoot	root	TMAR
Soil (control)	n.d.	0.03b	0.00b	n.d.	0.03b	0.00b
Soil + swine manure	2.61	4.49a	2.67a	3.69	6.62a	3.80a
Soil + compost	n.d.	0.40b	0.01b	n.d.	1.37b	0.03b
Soil + vermicompost	n.d.	0.47b	0.02b	n.d.	1.50b	0.03b
F value	-	**	**	-	**	**

Values in same letters in the columns are not significantly different (LSD test, p< 0.01), n.d.: Not detect

Table 4 Effect of swine manure, compost and vermicompost accumulation of Cu (mgkg^{-1}) in soil

Treatment	Korat soil series	Nampong soil series
Soil (control)	0.59b	0.11c
Soil + swine manure	6.29a	6.19a
Soil + compost	1.90b	1.64b
Soil + vermicompost	1.91b	1.70b
F value	**	**

Values in same letters in the columns are not significantly different (LSD test, p< 0.01)

Table 4 showed the Cu accumulation in Korat soil series was found higher than Nampong soil series at 6.29 and 6.19 mg/kg respectively when treated with swine manure. But there was no significant difference in the Cu content when treated with compost and vermicompost. This is because Korat soil contains clay mineral which absorbs Cu whereas Nampong soil series is more of sandy which absorbs less Cu. Clay is a potentially good adsorptive material because of its large surface area, high cation exchange capacity, chemical and mechanical stability, and layered structure (Nurdan and Okan, 2013).

CONCLUSION

Swine manure has a significant influence on the amount of Cu accumulation in root and shoot uptake by kale. The most of Cu in swine manure included exchangeable form and organic matter compound. Exchangeable form is availability of Cu and organic matter compound e.g. histidine, nicotianamide and citrate, appears as a key process that promotes root-to-shoot mobility of a metal via xylem transport. Therefore, accumulation of Cu high concentration in root and shoot when treat with swine manure However, accumulation of Cu in Kale and soil depend on kind difference of soil and texture. This is clay mineral cloud absorption heavy metal. Therefore Korat soil series contains clay mineral which absorbs Cu whereas Nampong soil series is more of sandy which absorbs less Cu.

ACKNOWLEDGEMENTS

The author thanks the Integrated Water Resource Management Research and Development Centre in Northeast Thailand, The Research Developing and Learning Centre on Earthworm for Agriculture and Environment, Scholarship of graduated school of Khon Kaen University and National Research Council of Thailand (NRCT) for financial support and Khon Kaen University Research Fund (Synchrotron KKU fund).

REFERENCES

Bremner, J.M. 1965. Cation exchang capacity. In Black, C.A. et al. (ed.) Methods of Soil Analysis, Part 2, Agronomy, 9, 1149-1278. Am. Soc. Agron., Inc., Madison, Wis.

Clemens, S., Palmgren, M.G. and Kramer, U. 2002. A long way ahead, Understanding and engineering plant metal accumulation. Trend Plant Science, 7, 309-315.

Horwitz, W. (Ed.). 2000. Official method of analysis of AOAC internation. 17th AOAC International Inc., Gaithersberg, MD.

Materechera, S.A. 2002. Nutrient availability and maize growth in soil amended with earthworm casts from a South Africac indigenous. Bioresource Technology, 84, 197-201.

Nurdan, G.T. and Okan, O. 2013. Study of montmorillonite clay for the removal of copper (II) by adsoption, Full factorial design approach and cascade forward neural network. The Scientific Journal, 1-11.

Olugbenga, J.O., Adriaan, R.J. and Andrei, R.B. 2010. Influence of clay content on bioavailability of copper in the earthworm *Eisenia fetida*. Ecotoxicology and Environmental Safety, 73, 407-414.

Ruiz, E., Rodriguez, L. and Alonso-Azcarate, J. 2009. Effects of earthworm on metal uptake of heavy metals from polluted mine soils by different crop plants. Chemosphere, 75, 1035-1041.

Sajidu, S.M.I., Persson, I., Masamba, W.R.L., Henry, E.M.T. and Kayambazinthu, D. 2006. Removal of Cd^{2+}, Cr^{3-}, Cu^{2+}, Hg^{2+}, Pb^{2+} and Zn^{2+} cations and as O_4^{3-} anions from aqueous solutions by mixed clay from Tundulu Malawi and characterisation of the clay. Water Sa., 4, 519-526.

Tessier, A., Cambell, P.G.C. and Bission, M. 1997. Sequential extraction procedure for the speciation of particulate trace metals. Analytical Chemistry, 51, 844-851.

Walkley, A. and Black, I.A. 1934. An examination of the digestion method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science, 37, 29-33.

Xu, Y., Yu, W., Ma, Q. and Zhou, H. 2013. Accumulation of copper and zine in soil and plant within ten-year application of different pig manure rates. Plant Soil Environment, 59, 492-499.