Res. Crop. **24** (2): 319-325 (2023) DOI: 10.31830/2348-7542.2023.ROC-11161
Printed in India

Effect of pineapple skin Bokashi on improvement of soil properties and growth of shallot (*Allium ascalonicum* L.)

AGUSALIM MASULILI*, AGUS SUYANTO, SETIAWAN, MULYADI AND PAIMAN[1]

Department of Agrotechnology, Faculty of Agriculture
Panca Bhakti University, Pontianak 78113, West Kalimantan, Indonesia
**(e-mail: agusalim@upb.ac.id)*

(Received: February 17, 2023/Accepted: April 22, 2023)

ABSTRACT

Shallot (*Allium ascalonicum* L.) is one of the horticultural crops that has high economic value, along with the increase in demand for this commodity. Alluvial is a type of soil with the potential for agricultural development, among others, and can be used to cultivate shallots. However, this soil has physical and chemical constraints that can inhibit plant growth, so it requires soil amendment treatment to improve it. This study aimed at determining the effect of a combination of cow dung compost and pineapple skin bokashi on the improvement of alluvial soil properties and the growth of shallot plants. The research used polybags and was carried out in the laboratory and greenhouse of the Faculty of Agriculture, Panca Bhakti University, Pontianak, West Kalimantan, Indonesia, lasting 60 days from February-April 2022. The study used a completely randomized design (CRD) with three replications. Each polybag was filled with 8 kg of soil and added the cow dung compost of 80 g. Then, the treatment of bokashi pineapple skin consisted of eight levels: 10, 20, 30, 40, 50, 60, 70 and 80 g/polybag. Each replication consisted of three plant samples so that the plant numbers were 72 units. The research results showed that the use of organic amendments of pineapple skin bokashi affected improving alluvial soil properties, which could reduce BD and increase soil pores, pH, organic C, P available and N total of soil. Furthermore, there was an increase in the growth of shallot plants as a result of the treatment given. The research findings showed that the best growth of shallots was achieved at the dose of 60 g/polybag pineapple skin bokashi. Furthermore, it can be recommended that further research be carried out on the effect of the combination of cow dung. compost and other organic and inorganic amendments.

Key words: Alluvial, bulk density, nitrogen, phosphate, pineapple skin, shallot

INTRODUCTION

Shallot (*Allium ascalonicum* L.) is a horticultural commodity with many benefits. Shallots have a high demand as a commodity with strategic and economic value. One *type of* soil that has the potential for shallot development is alluvial. Dwevedi *et al.* (2017) said that these soils have a wide variety of properties, and most of them are formed along streams. Alluvial soil properties depend highly on the parent material in which this soil is formed. Boettinger (2004) stated that this soil has soil physical and chemical constraints that can inhibit plant growth. Alluvial soil contains a lot of sand and clay and does not contain many elements of nutrition. The characteristics of alluvial soil are grey in colour with a slightly loose structure and sensitive to erosion. According to Ayu *et al.* (2021), fertility levels are moderate to high depending on the parent and climate. In Indonesia, alluvial soil is land widely used for seasonal to annual food crops.

In alluvial soils used for intensive agricultural activities, one of the important obstacles is the decreasing soil organic matter content. This happens because intensive tillage can increase the rate of decomposition. On the other hand, the continuous transport of crops can also result in reduced soil organic matter. Soil organic matter is a determinant of soil health and productivity, is central to many soil functions and ecosystem services, and is important for the soil's physical,

[1]Department of Agrotechnology, Faculty of Agriculture, Universitas PGRI Yogyakarta, Yogyakarta 55182, Indonesia.

chemical and biological health. Organic matter plays a role in soil granulation, as it can be a glue that holds soil minerals together.

To overcome the problem of alluvial soils, we need organic fixers, which are important in increasing soil organic matter content, improving air conditioning, physical, chemical and biological properties, and maintaining sustainable soil quality and health (Voltr *et al.*, 2021). One of the organic fixers is cow dung compost. Using cow manure compost can increase soil physical activity and plant productivity (Alwaneen, 2020). Cow dung and fly ash–bottom ash (FABA) compost can increase organic C, P available and N total in sandy soil (Faoziah *et al.*, 2022). Applying cow manure and poultry compost increases plant biomass and improves heavy metal content in irrigated soil contaminated with wastewater (Haroon *et al.*, 2020). Cow dung compost has high fiber content (Amandeep *et al.*, 2021; Nguyen and Tran, 2022), such as cellulose, confirmed by the measurement results of the parameter C/N ratio, which was quite high > 40. Besides that, it contains macronutrients such as N, P and K, as also other essential micronutrients. The application of cow dung compost can reduce soil salinity and pH (Li *et al.*, 2022), increase the diversity of soil bacteria and effectively regulate the community structure of soil bacteria (Zhang *et al.*, 2019). In addition, it can improve soil microorganisms' activity and soil fertility (Das *et al.*, 2017). With an increase in soil organic matter originating from the application of cow dung compost, it will support the life of microorganisms in the soil. It can play a role in converting organic matter into humus or certain compounds, which in turn can improve soil's physical properties (soil structure).

As an organic amendment, cow dung compost can be used as essential fertilizer, which can improve soil fertility and change various factors in the soil, thereby ensuring soil fertility. Suntoro *et al.* (2018) proved that the application of livestock manure compost significantly affects the increase in plant height, leaf area index, root weight, shoot weight and N total in the soil. Anwar *et al.* (2017) found that the use of livestock manure compost can increase the biomass, N and P content in spinach plants. Thus, using cow dung compost can improve alluvial soil properties and increase the growth of cultivated plants.

Apart from cow dung, the amendment that can be used as a material that can improve alluvial soil properties is organic waste from crops. Harvested organic waste, including composted pineapple skin has the potential to produce healthy food (Tibu *et al.*, 2019). Pineapple skin bokashi can be used as liquid organic fertilizer (LOF) to increase organic matter content and improve soil properties (Cristina *et al.*, 2022). Using liquid organic fertilizer from pineapple skin bokashi can improve soil pH and increase plant growth (Suryani *et al.*, 2022), and availability of N, P and K (Hindersah *et al.*, 2018). Pineapple skin bokashi can be used as a source of nutrients in a vermicompost system (Zziwa *et al.*, 2021), containing sufficient nutrients to improve soil properties and increase crop yields (Alasa *et al.*, 2021). With the excellent role of cow dung compost and pineapple skin bokashi, if applied to the soil together, it can improve soil properties and shallot growth.

The description above illustrates that the improvement of alluvial soil properties can be made through organic amendments. So far, there have been many studies on cow dung compost and pineapple skin bokashi, each individually, on plant growth. However, research on using these two ingredients together is still rare. For this reason, this study aimed at determining the effect of a combination of cow dung compost and pineapple skin bokashi on the improvement of alluvial soil properties and the growth of shallot plants.

MATERIALS AND METHODS

Study Site

The research was carried out in the laboratory and greenhouse of the Faculty of Agriculture, Panca Bhakti University, Pontianak, West Kalimantan Province, Indonesia. The time for implementation starts in February-April 2022. The altitude of the place where the research was carried out was 1 m above sea level, with an average temperature and humidity of 27.6^{o}C and 82.8%, respectively. The location of the research was in the position of latitude 2°05' LU–3° 05' S and longitude 108°30'-144°10' E.

Experimental Design

The research used polybags and was

carried out in the laboratory and greenhouse of the Faculty of Agriculture, Panca Bhakti University, Pontianak, West Kalimantan, Indonesia, lasting 60 days from February-April 2022. The study used a completely randomized design (CRD) with three replications. Each polybag was filled with 8 kg of soil and added the cow dung compost of 80 g. Then, the treatment of bokashi pineapple skin consisted of eight levels: 10, 20, 30, 40, 50, 60, 70 and 80 g/polybag. Each replication consisted of three plant samples so that the plant numbers were 72 units.

Research Implementation

Alluvial soil was taken around the farmer's land in Sungai Itik Village, Sungai Kakap District, Kubu Raya Regency, West Kalimantan Province, Indonesia. The location was an agricultural area designated as an integrated farming area development. The soil was taken compositely at a depth of 20 cm. Next, the soil was cleaned, mixed and air-dried, then put in an 8 kg/polybag.

Pineapple skin bokashi was taken pineapple skin waste from markets where pineapples were sold. Then chopped 1-2 cm in size, mixed with cow dung, husk and rice bran, and added effective microorganism-4 (EM_4) and granulated sugar. The mixture was stored in a secure place. The lid where the fermentation was opened every two days to control the temperature. After 14 days, pineapple skin bokashi can be used, with the characteristics of being brownish-black and odorless.

Alluvial soil that had been put into 72 polybags was placed according to the research design, then each polybag was added according to the dose level. Dolomitic lime was added as a soil amelioration agent and NPK Mutiara fertilizer (16:16:16) as a basic fertilizer. The shallot seeds were planted one week after the application of cow dung compost and pineapple skin bokashi treatment. Maintenance of shallot plants was carried out until they reach the age of 60 days. At the end of the study, the growth and yield of shallots were observed, and 100 g of undisturbed soil samples were taken to keep soil properties.

Observation Parameters

In this study, the observed parameters consisted of the physical and chemical properties of the soil, as well as the growth of shallot plants. The physical properties of the soil observed were bulk density (BD) and soil pore size. BD was measured using the adjusted clod method of Blake and Hartge (1986). Soil pore measurements were carried out at soil water content (v/v) with a matrix potential of 0 kPa. Furthermore, the chemical parameters of the soil consisted of soil pH, C organic, N total and P available. The pH observation was carried out by making a soil solution with a ratio of 1:2.5 (using deionized water), and then measuring it with a pH meter (Jenway 3305). C organic measurements were carried out according to the wet oxidation method described by Walkley and Black (1934). Redemption N total content, using the Kjeldhal method (Bremner and Mulvaney, 1982). For P-available used Bray I.

Shallot plant growth was carried out at the age of 60 days after planting. The growth parameters observed were plant height (cm), leaf numbers (strands), tuber numbers (tubers), root fresh weight (g) and tuber dry weight (g).

Statistical Analysis

Statistical analysis was carried out for each observation parameter to determine the effect of the combination dose of cow dung compost and pineapple skin bokashi on the physical and chemical properties of alluvial soil and growth parameters of shallot plants. The data were analyzed for analysis of variance (ANOVA) at the P=0.05 level of significance. Furthermore, there was a significant effect. In that case, a least significant difference (LSD) test at the P=0.05 level of significance for determining the difference between the mean treatment.

RESULTS AND DISCUSSION

Changes in Soil Properties

Treatment of organic amendments gave effective changes in soil properties. The processing of pineapple skin bokashi significantly affected changes in pH, C organic, P available, N total, BD and soil pores. In this regard, soil organic matter was a resource that could provide nutrients, reduce compaction,

Table 1. The effect of pineapple skin bokashi treatment on the improvement of soil properties

Pineapple skin bokashi treatment (g/polybag)	H_2O pH	C organic (%)	P available (%)	N total (%)	Bulk density (g/cm^3)	Soil porosity (%)
10	4.06a	4.16a	0.31a	3.44a	1.24e	5.54a
20	4.08a	4.52b	0.35b	3.51b	1.23de	6.15b
30	4.18bc	4.78b	0.37b	3.52b	1.20c	6.22b
40	4.39bc	4.79b	0.38b	3.56b	1.19c	9.73cd
50	4.48b	4.80b	0.38b	3.57b	1.19c	9.75d
60	4.58c	4.83bc	0.40c	3.60b	1.16b	9.74d
70	4.47bc	4.85bc	0.39bc	3.68bc	1.03a	9.75d
80	4.36bc	4.91c	0.37b	3.72c	1.02a	10.17e
Value of LSD	0.24	0.34	0.03	0.06	0.12	0.41

Figures followed by the same letter in the same column are not different based on the LSD test at the P=0.05 level of significance.

provide oxygen in the soil and affect plant growth (Table 1).

Table 1 shows that the pineapple skin bokashi had a significantly different effect on soil pH. The highest pH value (4.58) was obtained at a dose of 60 g/polybag and was significantly different from other treatments. Furthermore, the pH value decreased when the pineapple skin bokashi was increased to above 70 g/polybag. This means that increasing the number of organic amendments at a certain dose can cause an increase in soil acidity. This happens because organic amendments' decomposition into the soil releases organic acids, which can affect soil acidity. For C organic, Table 1 shows an increase with increasing doses of pineapple skin bokashi, where the highest value (4.91%) was achieved at a dose of 80 g/polybag. Adeleke *et al.* (2017) explained that organic matter in the soil underwent metabolic processes that could affect the C cycle, physical chemistry and soil ecology. From Table 1, the P available had changed due to the treatment given.

The highest P available (0.40%) was obtained in the pineapple skin bokashi at a dose of 60 g/polybag. In this regard, Zhang *et al.* (2021) stated that organic acids could activate P bound in the soil, so that it could be available. N total also changed, due to the influence of cow dung compost and pineapple skin bokashi. As seen in Table 1, the highest N total (3.72%) was obtained at the treatment dose of 80 g/polybag. The increase in N total occurred due to the addition of plant biomass (Wijanarko and Purwanto, 2017).

The physical properties of the soil also changed due to the treatment given. In Table 1, BD decreased when the dose of pineapple skin bokashi was increased, whereas the pore value of the soil increased with increasing doses of pineapple skin bokashi. The lowest BD value (1.02 g/cm^3) was achieved in pineapple skin bokashi at a dose of 80 g/polybag. The highest soil pore value (10.17%) was achieved at the same dosage treatment. From these results, it means that there was an improvement in the BD and soil pores due to the combination treatment of the organic amendments given. In line with this, Yahya *et al.* (2012), in alluvial soils, an important problem that can cause obstacles to the development of plant roots is soil compaction due to BD high and low soil pores. According to Cahyono *et al.* (2020), compost can improve the chemical and physical properties of the soil because it contains organic compounds. Widodo and Kusuma (2018) stated that soil loosening occurs, and the pore space increases. Reinforced by Cincotta *et al.* (2019), organic matter applied to the soil was further decomposed to produce organic substances, which could affect soil aggregation. Furthermore, Zhang *et al.* (2019) explained that components of organic matter in the form of humic acids played an important role in establishing the stability of soil aggregates by binding soil particles with their active groups. This was the main trigger in improving the physical properties of the soil.

Changes in the Growth of Shallot Plants

As a result of the improvement in soil properties, there was an influence on shallot growth. Table 2 shows a change in the growth parameters of shallots due to the influence of cow dung compost and pineapple skin bokashi.

Table 2. The effect of pineapple skin bokashi treatment on the growth of shallots

Bokashi treatment pineapple skin	Plant height (cm)	Leave numbers (strands)	Tuber numbers (tubers)	Root fresh weight (g)	Tuber dry weight (g)
10	23.33a	21.56a	4.78a	32.87a	25.83a
20	24.11ab	24.22ab	5.33b	33.33a	25.85a
30	25.67b	25.00b	5.59bc	33.58b	25.98b
40	26.37bc	26.67c	5.67c	35.34cde	26.52c
50	26.44c	26.56c	5.44b	38.69d	26.57c
60	26.56c	32.56d	6.78d	41.95e	31.62e
70	29.78e	31.67d	5.33b	38.69d	30.02de
80	27.89de	31.56d	6.78d	34.30b	27.30d
Value of LSD	2.24	3.34	0.54	0.69	0.14

Figures followed by the same letter in the same column are not different based on the LSD test at the P=0.05 level of significance.

The highest plant height (29.78 cm) was obtained at a dose of 70 g/polybag pineapple skin bokashi, not different from 80 g/polybag (27.89 cm).

Table 2 shows that the highest was obtained at a dose of 60 g/polybag, resulted in 32.56 strands, and decreased when the pineapple skin bokashi was increased. From the results of these observations, the growth of shallot plants occurred due to adding organic amendments to the soil. In line with this, Dhillon *et al.* (2018) suggested that continuous manure application could maintain soil organic matter, affecting plant growth and yield. Emphasized by Wibowo and Kasno (2021), organic matter is an indicator of soil quality; the higher the soil's organic carbon content, the higher the ability of the soil to hold nitrogen, which will affect plant growth.

Table 2 shows that the highest value for each parameter, namely, the number of tubers (6.78 tubers), the fresh weight of the tubers (41.95 g) and the dry weight of the shallot bulb (31.62 g) were obtained at the pineapple skin bokashi at a dose of 60 g/polybag. One of the important reasons for this result is that organic amendments can produce humus substances, which improve soil properties, increasing the growth of shallots. This was supported by Dergam and Abdulrazzak (2022) showed that humic acid added to the soil could improve the physical and chemical properties of the soil. Humic acid can increase plants' growth and fresh and dry biomass.

Table 2 explains that a decrease in the shallot growth value when the pineapple skin bokashi dose was higher. This means the doses that are too high could inhibit shallot growth. This phenomenon indicated that the growth of shallots required a balance of various physical and chemical soil properties. Organic fixers affected the improvement of soil quality and increased plant growth. Cahyono *et al.* (2020) found that compost could improve acid soil properties. Furthermore, Frimpong *et al.* (2021) stated that compost can improve soil quality, including CEC and pH. The improvement in soil properties, in turn, will have a good effect on shallot growth.

CONCLUSION

From the results of this study, it can be concluded that the use of organic amendments of pineapple skin bokashi affects improving alluvial soil properties, which can reduce BD and increase soil pores, pH, organic C, P available and N total of soil. Furthermore, there was an increase in the growth of shallot plants as a result of the treatment given. The research findings showed that the best growth of shallots was achieved at the dose of 60 g/polybag pineapple skin bokashi. Furthermore, it can be recommended that further research be carried out on the effect of the combination of cow dung compost and other organic and inorganic amendments.

ACKNOWLEDGEMENTS

Funds supported this research from the Panca Bhakti University Research and Community Service Institute. For this reason, the authors thank you for the financial support so that the research process can be carried out properly. Thanks also due to the Faculty of Agriculture, Panca Bhakti University, which has facilitated the use of laboratory equipment for research.

REFERENCES

Adeleke, R., Nwangburuka, C. and Oboirien, B. (2017). Origins, roles and fate of organic acids in soils: A review. *South African J. Bot.* **108**: 393-06.

Alasa, J. J., Bashir, A. U., Mustapha, M. and Muhammed, B. (2021). Experimental study on the use of banana and pineapple peel waste as biofertilizers, tested on *Hibiscus sabdariffa* plant: Promoting sustainable agriculture and environmental sanitation. *Arid Zone J. Eng. Technol. Environ.* **17**: 211-20.

Alwaneen, W. S. (2020). Effect of cow manure compost on chemical and microbiological soil properties in Saudi Arabia. *Pak. J. Biol. Sci.* **23**: 940-45.

Amandeep, Singh, G., Ram, M. and Batham, P. (2021). Effects of indigenous plant extracts with cow urine on incidence of stem borer, *Scirpophaga incertulas* (Walker) in paddy (*Oryza sativa* L.). *Crop Res.* **56**: 341-45.

Anwar, Z., Irshad, M., Mahmood, Q., Hafeez, F. and Bilal, M. (2017). Nutrient uptake and growth of spinach as affected by cow manure co-composted with poplar leaf litter. *Int. J. Recycl. Org. Waste Agric.* **6**: 79-88.

Ayu, A. S., Reny, S., Ida, M., Jaka, S., Laela, R. U. I, Dinar, Yayan, S., Yadi I. A, Umar, D. and Suhaeni (2021). Prediction model of production patterns of shallot development in the highlands of Indonesia. *Res. Crop.* **22**: 895-900.

Blake, G. R. and Hartge, K. H. (1986). Bulk density. In Methods of soil analysis, Part 1: Physical and mineralogical methods; Klute, A. (ed.); Soil Science Society of America: Madison, Wisconsin. pp. 363-75.

Boettinger, J. L. (2004). Alluvium and alluvial soils. *Encyclopedia of Soils in the Environment* **4**: 45-49.

Bremner, J. M. and Mulvaney, C. S. (1982). Nitrogen-total. In: Methods of soil analysis. Part 2. Chemical and microbiological properties, Page, A. L., Miller, R. H. and Keeney, D. R. Eds., American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin. pp. 595-24.

Cahyono, P., Loekito, S., Wiharso, D., Afandi, Rahmat, A., Nishimura, N. and Senge, M. (2020). Effects of compost on soil properties and yield of pineapple (*Ananas comusus* L. Merr.) on red acid soil, Lampung, Indonesia. *Int. J. Geomate* **19**: 33-39.

Cincotta, M. M., Perdrial, J. N., Shavitz, A., Libenson, A., Landsman-Gerjoi, M., Perdrial, N., Armfield, J., Adler, T. and Shanley, J. B. (2019). Soil aggregates as a source of dissolved organic carbon to streams: An experimental study on the effect of solution chemistry on water extractable carbon. *Front. Environ. Sci.* **7** : 1-14.

Cristina, E. F., Inonu, I. and Khodijah, N. S. (2022). Utilization of liquid organic fertilizer of pineapple peel waste for shallots cultivation (*Allium ascalonicum* L.). *J. J. Suboptimal Lands* **11**: 1-13.

Das, S., Jeong, S. T., Das, S. and Kim, P. J. (2017). Composted cattle manure increases microbial activity and soil fertility more than composted swine manure in a submerged rice paddy. *Front. Microbiol.* **8**: 1-10.

Dergam, H. and Abdulrazzak, O. (2022). Effect of humic acid on soil properties and productivity of maize irrigated with saline water. *Environ. Sci. Proc.* **16**: 2-4.

Dhillon, J., Del Corso, M. R., Figueiredo, B., Nambi, E. and Raun, W. (2018). Soil organic carbon, total nitrogen, and soil pH in a long-term continuous winter wheat (*Triticum aestivum* L.) experiment. *Commun. Soil Sci. Plant Anal.* **49**: 803-13.

Dwevedi, A., Kumar, P., Kumar, P., Kumar, Y., Sharma, Y. K. and Kayastha, A. M. (2017). Soil sensors: detailed insight into research updates, significance, and future prospects. In: *New pesticides and soil sensors*. pp. 561-94.

Faoziah, N., Iskandar and Djajakirana, G. (2022). The effect of the addition of cow dung compost and FABA on the chemical characteristics of sandy soil and the growth of tomato plants. *J. Soil Environ. Sci.* **24**: 1-5.

Frimpong, K. A., Abban-Baidoo, E. and Marschner, B. (2021). Can the combined application of compost and biochar improve the quality of a highly weathered coastal savanna soil? *Heliyon* **7**: *doi.org/10.1016/j.heliyon.2021.e07089.*

Haroon, B., Hassan, A., Abbasi, A. M., Ping, A., Yang, S. and Irshad, M. (2020). Effects of co-composted cow manure and poultry litter on the extractability and bioavailability of trace metals from the contaminated soil irrigated with wastewater. *J. Water Reuse Desalin.* **10**: 17-29.

Li, S., Liu, Z., Li, J., Liu, Z., Gu, X. and Shi, L. (2022). Cow manure compost promotes maize growth and improves soil quality in saline-alkali soil: the role of fertilizer addition rate and application depth. Sustainability (Switzerland) **14**: doi.org/10.3390/su141610088.

Nguyen, V. D. and Tran, D. H. (2022). Response of okra (*Abelmoschus esculentus*) to cow dung compost in central Vietnam. *Res. Crop.* **23**: 375-79.

Suntoro, S., Widijanto, H., Suryono, Syamsiyah, J., Afinda, D. W., Dimasyuri, N. R. and Triyas, V. (2018). Effect of cow manure and dolomite on nutrient uptake and growth of corn (*Zea mays* L.). *Bulg. J. Agric. Sci.* **24**: 1020-26.

Suryani, R., Masulili, A., Sutikarini, S. and Tamtomo, F. (2022). Utilization of liquid organic fertilizer of pineapple waste to improve growth of sweet corn plant in red yellow podsolic soil. *Int. J. Multidiscip. Sci.* **5**: 30-36.

Tibu, C., Annang, T. Y., Solomon, N. and Yirenya-Tawiah, D. (2019). Effect of the composting process on physicochemical properties and concentration of heavy metals in market waste with additive materials in the Ga West Municipality, Ghana. *Int. J. Recycl. Org. Waste Agric.* **8**: 393-403.

Voltr, V., Menšík, L., Hlisnikovský, L., Hruška, M., Pokorný, E. and Pospíšilová, L. (2021). The soil organic matter in connection with soil properties and soil inputs. *Agronomy* **11**: 1-21.

Walkley, A. J. and Black, I. A. (1934). Estimation of soil organic carbon by the chromic acid titration method. *Soil Sci.* **37**: 29-38.

Wibowo, H. and Kasno, A. (2021). Soil organic carbon and total nitrogen dynamics in paddy soils on the Java Island, Indonesia. *IOP Conf. Series: Earth Environ. Sci.* **648**: *doi: 10.1088/1755-1315/648/1/012192.*

Widodo, K. H. and Kusuma, Z. (2018). Effects of compost on soul physical properties and growth of maize on an inceptisol. *J. Land Land Resour.* **5**: 959-67.

Wijanarko, A. and Purwanto, B. H. (2017). Effect of land use and organic matter on nitrogen and carbon labile fractions in a Typic Haplodult. *J. Degraded and Mining Lands Manage.* **4** : 837-43.

Yahya, Z., Mohammed, A. T., Harun, M. H. and Shuib, A. R. (2012). Oil palm adaptation to compacted alluvial soil (typic endoaquepts) in Malaysia. *J. Oil Palm Res.* **24**: 1533-41.

Zhang, J, Gao, L., Pang, Z., Liu, L., Chen, X., Wang, S., Wang, H., Tong, R., Shi, C. and Chen, X. (2021). Effect of low-molecular-weight organic acids on phosphorus soil activation: A laboratory study of the soils from Wangbeng section of the Huaihe River Basin, China. *Plants Soil Environ.* **67**: 660-67.

Zhang, J., Chi, F., Wei, D., Zhou, B., Cai, S., Li, Y., Kuang, E., Sun, L. and Li, L. J. (2019). Impacts of long-term fertilization on the molecular structure of humic acid and organic carbon content in soil aggregates in black soil. *Sci. Rep.* **9**: 1-7.

Zziwa, A., Jjagwe, J., Kizito, S., Kabenge, I., Komakech, A. J. and Kayondo, H. (2021). Nutrient recovery from pineapple waste through controlled batch and continuous vermicomposting systems. *J. Environ. Manag.* **279**: *doi: 10.1016/j.jenvman.2020. 111784.*