Food Research 7 (Suppl. 2) : 70 - 77 (2023)
Journal homepage: https://www.myfoodresearch.com

FULL PAPER

The effect of pineapple peel wastes as liquid organic fertiliser on growth character of okra (*Abelmoschus esculentus* L.)

[1]Seman, N.A. and [2,*]Adam, S.

[1]*Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA Cawangan Melaka Kampus Jasin, 77300 Merlimau Melaka, Malaysia*
[2]*Soil Conservation and Management Research Interest Group, Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA Cawangan Melaka Kampus, Jasin,77300 Merlimau Melaka, Malaysia*

Article history:
Received: 1 September 2022
Received in revised form: 19 October 2022
Accepted: 22 October 2022
Available Online: 25 September 2023

Keywords:
Pineapple peels,
Liquid organic fertiliser,
Okra,
Soil chemical properties

DOI:
https://doi.org/10.26656/fr.2017.7(S2).7

Abstract

The processing of salads, juices, and jams from pineapples is widely produced from pineapple peels. This study evaluated the effect of pineapple peels as a liquid organic fertiliser (LOF) on the growth character of okra (*Abelmoschus esculentus* L.) and selected soil chemical properties. Different percentages of pineapple peels' LOF were applied to the growth medium of okra: T1 (control), T2 (3%), T3 (6%), T4 (9%), T5 (12%), and T6 (15%) and these treatments were arranged in Randomised Complete Block Design (RCBD), along with four replications. The results of this study indicated that the use of LOF did not have a significant effect on the growth of okra ($p>0.05$). However, the growth of okra tended to be better at T4 (9%) and the high percentage (T6: 15%) of LOF showed a reduction of growth parameters. The result of soil chemical properties revealed that the high rate (6-15%) of LOF significantly improved soil pH. The macronutrients and micronutrients displayed no significant results, except for Ca and Mg.

1. Introduction

The pineapple (*Ananas comosus*) is a monocotyledonous plant that belongs to bromeliad family and bromelioideae subfamily (Saito and Harborne, 1983). It is one of the world's most frequently consumed fruits, either directly or as a by-product of processed foods, such as syrups, vinegar, wines, liqueurs, flour, and livestock feed (Baidhe *et al*., 2021). The demand for pineapples is increasing throughout the year because they contain all the good nutritious nutrients that humans require. Pineapples comprise mostly carbs and water, and it is an excellent source of dietary fibres, sugars, organic acid, vitamins, and minerals, as well as bromelain. Bromelain is a proteolytic enzyme that helps digestion and has anti-inflammatory, antioxidant, anti-cancer, and cardioprotective properties (Hikisz and Bernasinska-Slomczewska, 2021). The pineapple market has expanded significantly because of the appealing fragrance components and nutritious qualities, as well as high demand and competitive retail pricing (Abu Bakar *et al*., 2013). The biggest countries that produce pineapples are Costa Rica (3056.45 metric tonnes), followed by the Philippines (2671.71 metric tonnes), Brazil (2253.90 metric tonnes), Thailand (2153.18 metric tonnes), and lastly India (1891.00 metric tonnes). They were the top five pineapple producers globally in 2017 (Statista, 2020). In Malaysia, Johor was known as the biggest pineapple producer in 2017 (274,284 metric tonnes) (DOA, 2018). Other states such as Sarawak, Perak, Kedah, Pahang, and Selangor's pineapple plantations have also expanded rapidly due to the increasing demand for this fruit because of its nutritional value.

As a consequence of the increasing production and demand for pineapples in this country, there are abundance amount of waste products derived from the pineapple industry. Two types of waste materials from the pineapple industries are derived from fields and mills. The most common types of field wastes are crowns, bark, and leaves, which are frequently burned in the centre of fields after the fruit harvest (Reinhardt *et al*., 2018). This can cause pollution to the environment, such as air pollution. Meanwhile, the wastes at mills consist of pineapple peels, which also contributed to pollution if the mills do not properly manage the waste. Even though these wastes cannot be eaten, they contain significant amounts of carbs, including non-digestible proteins and fibres (Al-Sayed and Ahmed, 2013). Improper management of pineapple wastes leads to generating both greenhouse gases (GHG) and waste

*Corresponding author.
Email: *salwa@uitm.edu.my*

eISSN: 2550-2166
Published by Rynnye Lyan Resources

fluids with high biological and chemical oxygen needs, causing environmental and sanitary concerns, as well as endangering the well-being of those in the nearby areas (Bhatnagar *et al*., 2015). Greenhouse gases contribute to climate change by trapping heat. These gases also contribute to respiratory illness caused by smog and air pollution. Other impacts of climate change produced by greenhouse gases include extreme weather, food supply problems, and increasing wildfires. Wastes from farms can also form a habitat for pests and diseases, which can have harmful effects, especially rats. Rats will transmit illnesses, such as leptospirosis, which are extremely dangerous to humans if ingested. Direct transmission occurs from host to host, whereas indirect transmission occurs through the soil, infected animal urine, or polluted water (Haake and Levett, 2015). Humans can be unintentional hosts, shedding leptospires through urine (Haake and Levett, 2015). Leptospires spread hematogenously and infect host tissues once it enters the body (Wunder *et al*., 2016). In the worst-case scenario, it can cause death to humans.

Therefore, the management of pineapple waste is very important in the pineapple industry. Waste management, often known as waste disposal, refers to all the steps involved in handling unwanted or rejected materials from the point of origin to the final stage of disposal. After water quality, the second most troubling issue impacting emerging nations is solid waste management (Senkoro, 2003). Composting, landfilling, anaerobic digestion, pyrolysis and gasification, as well as incineration are examples of waste management methods that can be practised in pineapple industries to decrease pollution and sustain the environment. This is to ensure that the wastes are fully utilised without causing any harmful effects on the environment. A well-managed waste stream will provide sustainability, as well as clean, easily marketable, and environmentally friendly finished products (Mahmud *et al*., 2016).

Previous researchers have revealed the potential of fruit wastes as a source of raw materials that can be converted into value-added products or incorporated into a variety of biotechnological applications such as bio-fertiliser production, animal food and feed production, industrial chemicals or raw materials, biofuels and other alternative renewable energy development, water treatment application, as well as food and pharmaceutical industrial applications (Sagar *et al*., 2018), as cited by Alasa (2021). Alasa (2021) also cited that based on scientific findings, fruit wastes contain a variety of natural bioactive compounds that are beneficial to plant growth (Vasanthi and Ramadas, 2019).

Thus, using fruit wastes as fertilisers for crops could result in long-term plant growth and a clean environment. In order to convert the wastes into fertilisers, the wastes need to be composted. Composting is the natural method of converting organic materials like leaves and discarded food into usable products that can be applied as soil amendments to enhance soil properties and plant growth. The fertilisers derived from composting fruit waste-based offer a number of benefits for plants through improved soil morphology and organic matter content (Adalgisa *et al*., 2005). They also improve soil pH and fertility (Panwar, 2015), as well as enhance soil microbial activity (Rai *et al*., 2014), and protect plants from insects, nematodes, fungi, and other plant pathogens (Divina, 2016).

Meanwhile, the use of fertilisers through composting plant residues helps increase the soil's sustainable health compared to inorganic fertilisers. Inorganic fertilisers release nutrients quickly, but most of them leach out easily, which contributes to environmental and health implications. The addition of organic amendments to the soil at different rates has been reported to increase the yield of okra and improve soil nutrient contents (Akanbi *et al*., 2000). Furthermore, the use of organic fertilisers through the utilisation of agricultural wastes could reduce the cost of buying chemical fertilisers which is a burden to farmers, particularly vegetable crop growers (Olasantan, 1991). Therefore, the major aim of this study was to investigate the effects of pineapple peels as a liquid organic fertiliser (LOF) on the growth character of okra (*Abelmoschus esculentus* L.) and to determine selected soil chemical properties with the application of LOF. The findings of this study may promote the recycling or reutilisation of fruit waste-based organic fertilisers to ensure the long-term sustainability of the environment.

2. Materials and methods

2.1 Soil sampling and preparation

Soil sampling was carried out to characterise the soil used for the experiment. The soil samples were collected at the surface of UiTM Jasin Share Farm's soil of about 0 to 15 cm depth. These soil samples were used as planting media for okra cultivation. Then, several collected soil samples were air-dried, crushed using mortar, pestle, and then sieved through 2 mm mesh. The sieved samples were analysed for soil physico-chemical characteristics. The result of the soil physico-chemical analysis is shown in Table 1.

2.2 Preparation of liquid organic fertiliser derives from pineapple peels

In this study, pineapple peel wastes were used as LOF materials. The wastes of pineapple peels were chopped into smaller pieces and later ground to

https://doi.org/10.26656/fr.2017.7(S2).7

accelerate the composting process by the microorganisms. Before grinding, the pineapple peels were washed and cleaned using running water to dispose of the remaining chemical substances, such as pesticides and herbicides. After that, the pineapple peels were mixed with a few other materials to create a decent LOF, such as Effective Microorganism (EM), lime, brown sugar (molasses), and rice washing water. These materials were added to the LOF as a food source for the microbes to perform the composting process. Then, the LOF was kept in a tightly closed container and stored at room temperature where there was no sunlight. This was because the sunlight might inhibit the production and development of the effective microorganism in the LOF and take 30-40 days for the LOF to be ready.

Table 1. Soil chemical properties.

Soil Properties	
pH	3.93
Extractable P (mg/kg)	1.03
Available K (mg/kg)	16.24
Available Ca (mg/kg)	49.18
Available Mg (mg/kg)	3.99
Available Fe (mg/kg)	78.43
Available Zn (mg/kg)	0.356
Available Mn (mg/kg)	1.143
Available Cu (mg/kg)	0.296

2.3 Experimental procedures

The experiment made use of twenty-four polybags. They were filled with topsoil collected from the share farm. The experimental design was arranged according to Random Complete Block Design (RCBD) along with four replications. The treatment of this study involved different rates of LOF: T1 (0%), T2 (3%), T3 (6%), T4 (9%), T5 (12%), and T6 (15%). The transplanting of okra seedlings into the polybag was done after a week. Plant growth parameters such as plant height and the number of leaves were taken at three days intervals for 18 days. After the 18-day duration, the plants were uprooted and taken to the laboratory. The root length and plant biomass were determined.

2.4 The chemical analysis of the soil treated with liquid organic fertiliser

The chemical analysis of the soil treated with LOF was measured in this study. The analysis included the soil pH, extractable phosphorus (P), available potassium (K), magnesium (Mg), and calcium (Ca), as well as available micronutrients iron (Fe), manganese (Mn), Copper (Cu), and zinc (Zn). The pH of the soil was measured using a pH meter after calibration with buffer solutions with pH values of 4 and 7. The extractable P was determined by using Bray II solution method, and the available K, Mg, and Ca were determined by applying the modified shaking method using 1 M of ammonium acetate (NH_4OAc). Meanwhile, soil micronutrients like Fe, Mn, Cu, and Zn, were determined by using Mehlich No. 1 solution. All the macronutrients and micronutrient filtrate were determined by using an Inductively Coupled Plasma Optimal Emission Spectrometer (ICP-OES).

3. Results and discussion

3.1 Soil analysis

According to Table 1, the soil pH was low, indicating that it is acidic. Meanwhile, the values for P, K, Ca, and Mg macronutrients, as well as Fe, Zn, Mn, and Cu micronutrients, were low.

3.2 Plant growth parameter

3.2.1 Plant height

The progress of plant height for the okra plant is shown in Figure 1. In early growth, the plant height did not show differences until 12 of DAP (day after planting). The plant height began to vary. T5 (12%) hit the maximum plant height after being treated with LOF whilst T1 hit the lowest. However, no significant differences ($p = 0.234$) in plant height were recorded (Figure 2) for both control and treatment applications among all six collected data. Figure 2 illustrates that the

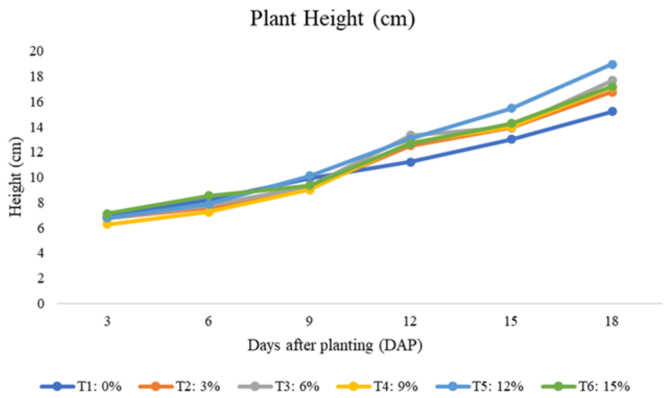

Figure 1. The effect of different percentages of LOF on plant height (cm).

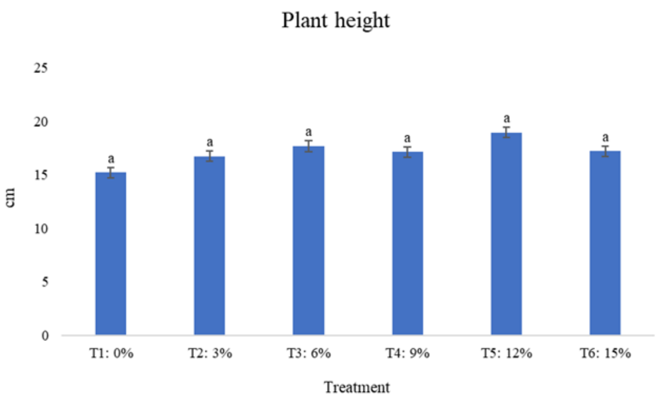

Figure 2. The mean comparison of plant height on different percentages of LOF.

https://doi.org/10.26656/fr.2017.7(S2).7

application of LOF slightly increased the plant height. This finding was similar to Sutanto *et al*. (2016) in which the pineapple liquid waste could increase the plant height for orchids and result in better plant growth.

3.2.2 Number of leaves

Figure 3 displays the number of leaves for the okra plant. The number of leaves from 3 to 6 DAP was not varied. However, the number of leaves began to differ on 9 DAP. T5 (12%) had the most leaves, while T6 (15%) had the fewest number of leaves. As shown in Figure 4 above, no significant differences (p = 0.548) in the number of leaves recorded for both control and treatment applications among all six collected data. The application of LOF slightly increased the number of leaves. This result was similar to Sutanto *et al*. (2016) which reported that the application of pineapple liquid waste could increase the number of leaves. However, in contrast to previous research by Mahmud *et al*. (2016), the high rate of pineapple biomass application resulted in decreased plant growth and inhibited the development of other parts of the plant, such as the number of leaves. From this study, the LOF showed a high EC reading (>4.0 mS) which might affect the plant growth performances. The accumulation and presence of salt in the soil inhibited the plant's ability to absorb water, resulting in slower growth development. Salt stress has an impact on all the major activities in plants, including plant growth and development (Parihar *et al*., 2015). The findings from this study were supported by past studies where the number of leaves decreased as plant development was inhibited due to the high application rate of LOF (15%).

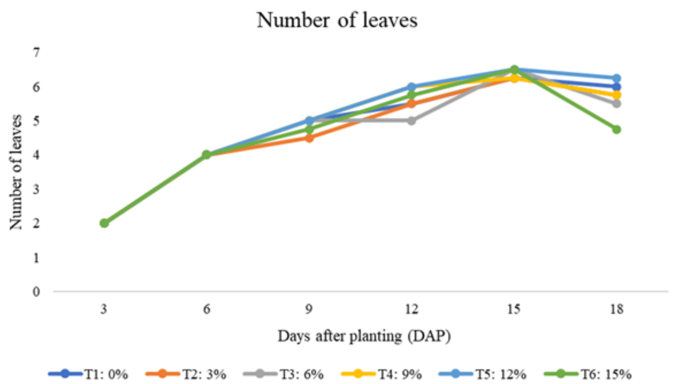

Figure 3. The effect of different percentages of LOF on the number of leaves.

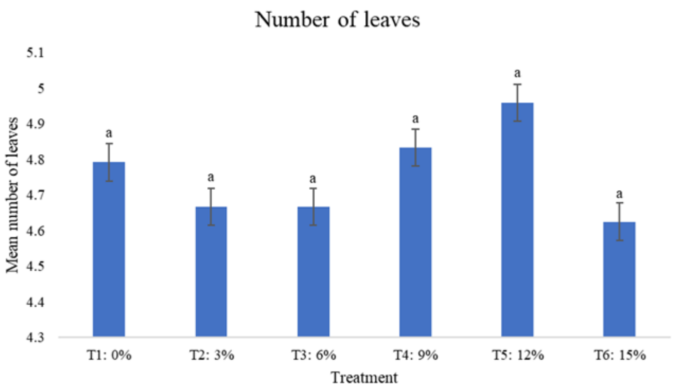

Figure 4. The mean comparison of number of leaves on the different percentages of LOF.

3.2.3 Root length

Based on the collected data for both control and treatment applications, there are no significant differences (p = 0.581) were found for root length. Even so, based on Figure 5, T2 (3%) recorded the highest mean for root length compared to other treatments. In contrast to previous research by Hindersah *et al*. (2018), at day 30 of soil treated with pineapple liquid waste and cow dung compost, root length was influenced significantly. The treatment, however, had no significant effect on root length at day 60. According to prior research by Viator *et al*. (2002), compost treatment had no significant effects on root length and root width. Having compost in the root zone appears to have reduced root development and proliferation for the within-row treatment vs. the control, as seen by the tendency toward shorter roots. This finding by Viator *et al*. (2002) was similar to this study where T2 (3%) had the highest root length while T6 (15%) had the lowest.

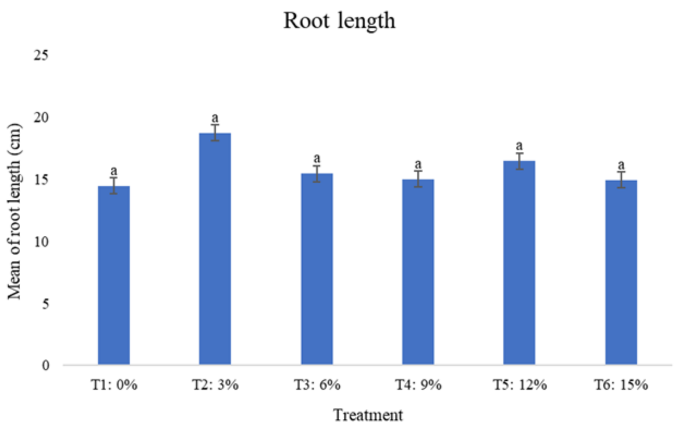

Figure 5. The mean comparison of root length on different percentages of LOF.

3.2.4 Plant biomass

Based on the collected data for both control and treatment applications, no significant differences (p = 0.661) were found for the plant biomass. However, based on Figure 6, T4 (9%) recorded the highest mean in plant biomass followed by T5 (12%). In accordance with Hindersah *et al*. (2018), the pineapple liquid waste and cow dung had no significant effects on the fresh weight of the plant. This is supported by a prior study by Mahmud *et al*. (2016), whereby the higher rate of pineapple biomass application resulted in lower plant development. This was also probably due to a high EC reading of the LOF which caused salt stress in plants. When there is excessive salt in the soil solution, the development of plant growth will be disrupted (Parihar *et al*., 2015).

https://doi.org/10.26656/fr.2017.7(S2).7

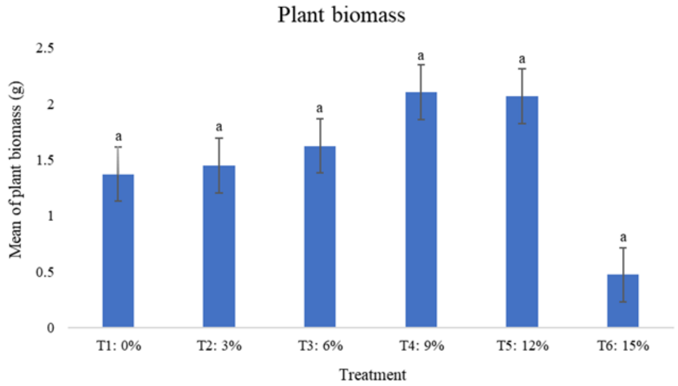

Figure 6. The mean comparison of plant biomass on different percentages of LOF.

3.3 Soil chemical properties treated with liquid organic fertiliser

3.3.1 Soil pH

There were significant differences (p=0.003) between control and treatment applications for the parameter of soil pH. The Tukey test showed no significant differences in presence among all treatments except for T4 and T6. It was noticed that the high rate of LOF (6-15%) slightly increased the soil pH. T4 (9%) revealed the highest soil pH, which was 4.35 (Figure 7). Nevertheless, it was still considered in an acidic condition. The lowest was T1 (control) with a soil pH of 3.93. The low rate of LOF application, which was T2 (3%), displayed a very low soil pH which was 4.03. According to Nadzirah *et al*. (2013), this was due to the pH of the pineapple peels itself which was already acidic with a pH ranging from 3.24-3.84. The increase in the rate of LOF application would result in the increase of soil pH, except for T5 (12%). Based on the laboratory test, the pH reading for the LOF was 4.69, while the EC reading was 8.8 which was too high and might inhibit plant development. As claimed by Kamaluddin and Zwiazek (2004), the acidic pH of the soil will cause a large and rapid decrease in water flow. Furthermore, according to Alam *et al*. (1999), the role of acidic pH in soil has often been considered to be detrimental in causing deficient nutrient availability and subsequently affecting plant development.

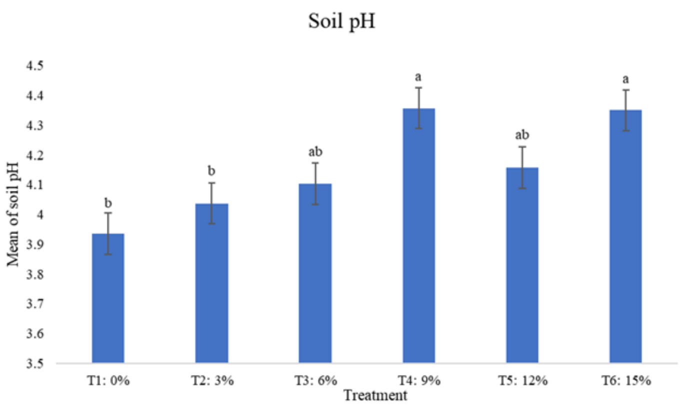

Figure 7. The mean comparison of comparison of soil pH on the different percentages of LOF.

3.3.2 Macronutrients P, K, Ca, and Mg

There were significant differences between macronutrients Ca (p = 0.013) and Mg (p = 0.00) among all the treatments. However, no significant differences between macronutrients for the P (p = 0.546) and K (p = 0.79) were recorded. It was recorded that T4 (9%) and T5 (12%) had no differences for Ca, yet T6 (15%) recorded the highest Ca. Besides, among T2 (3%), T3 (6%), and T4 (9%), it was observed that there were no differences for Mg, but T6 (15%) recorded the highest Mg. Based on Figure 8, it was observed that the application of LOF slightly increased the P content in soil for plant uptake and subsequently improved the overall plant growth. The results of Ca content were parallel to the results of soil pH where there was an increase in the Ca content which aligned with the increase of soil pH. The application of LOF also increased the macronutrient content in soil, however, there were no significant differences between P and K. Among the macronutrients, the highest was Ca (95–263 mg/kg). It was noticed that the lowest macronutrients were P (13-31 mg/kg). T1 (control) exhibited low P content which contributed to low plant height and root length. As stated by Verdonck (1997), green materials such as fruit scarps are typically found in low nutrients and the short period of composting also causes low nutrient availability in compost. According to Agegnehu *et al*. (2014), compost has a significant amount of major plant nutrients, such as N, P, K, Ca, Mg, and S, as well as the amount of key trace elements. Hence, compost may be considered an organic multi-nutrient fertiliser (Amlinger *et al*., 2007).

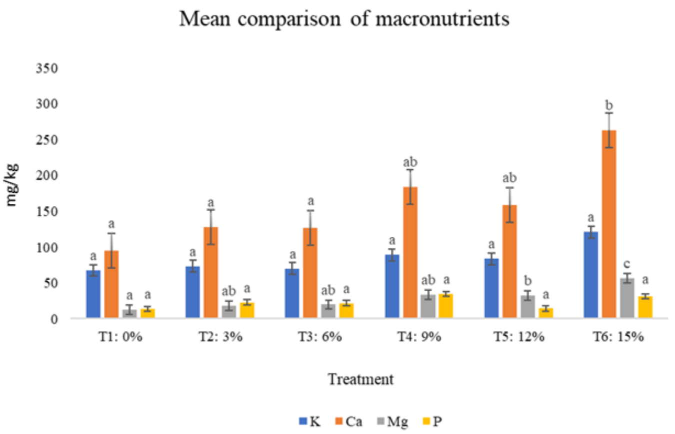

Figure 8. The mean comparison of macronutrients on different percentages of LOF.

3.3.3 Micronutrients Fe, Mn, Cu, and Zn

There were no significant differences among all treatments for Fe, Mn, Cu, and Zn. However, Fe displayed the highest micronutrients compared to other elements (122-140 mg/kg) as shown in Figure 9. It was

https://doi.org/10.26656/fr.2017.7(S2).7

observed that T3 (6%) illustrated the highest Fe whereas T4 (9%) recorded the lowest Fe. Meanwhile, T5 (12%) showed the lowest Mn and Zn, but high in Fe as it was the third highest after T3 (6%) and T2 (3%) (Figure 10). According to Tavakoli *et al.* (2014), even though plants need a small amount of micronutrients, it also plays a significant role in plant growth, such as manganese (Mn) plays a crucial role in oxidation and reduction processes, as electron transport in the photosynthesis process. As reported by Malakouti (2008), plant growth is inhibited and crop yield suffers as a result of micronutrient deficiency in soil content. This is supported by Cakmak (2002) and Malakouti (2007), where the deficiency of micronutrients in the soil can greatly disrupt plant yield and quality. In fact, the high content of iron (Fe) contributes to the low availability of phosphorus (P) in soil and subsequently affects plant growth. According to Hamad *et al.* (1992), high iron (Fe) content in the soil is generally seen as P-limited due to a proposed stable P binding at Fe compounds. The effect of high iron (Fe) on plant growth will reduce plant biomass, root growth inhibition, leaf bronzing, and necrosis (Zhang *et al.*, 2018).

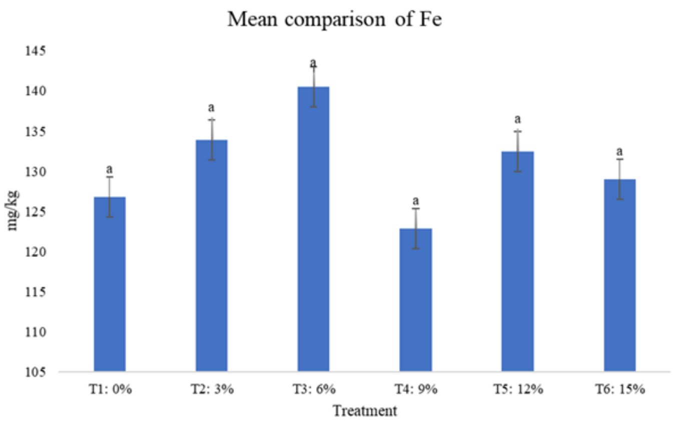

Figure 9. The mean comparison of Fe on different percentages of LOF.

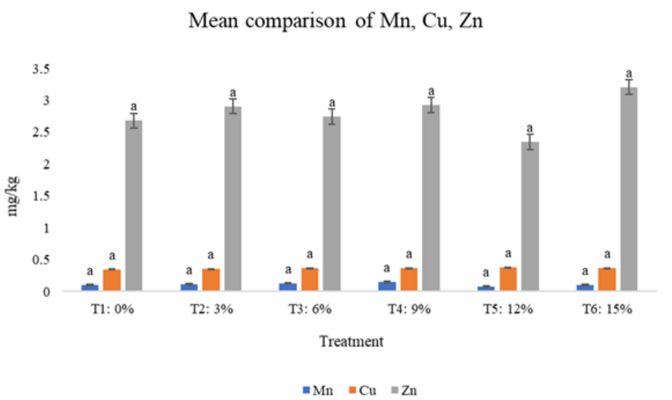

Figure 10. The mean comparison of micronutrients (Mn, Cu, Zn) on different percentages of LOF.

4. Conclusion

To summarise, the application of liquid organic fertiliser (LOF) derived from pineapple peels slightly improved the growth performance of okra and increased nutrient content, especially Ca and Mg in the soil. The growth of okra tended to be better at T4 (9%). However, the high rate of LOF, which was T6 (15%), was less suitable for plant growth due to the low growth performance of okra. The chemical properties of soil treated with LOF showed a slight improvement, particularly for P content which is important for early plant development, especially for root formation. Thus, the enhancement of LOF with P content is important to enrich the properties of LOF to support plant growth.

Conflict of interests

The authors declare no conflict of interest.

Acknowledgements

Special thanks to the Faculty of Plantation and Agrotechnology, UiTM Melaka Jasin Campus for providing all the facilities to complete this research.

References

Abu Bakar, B.H., Ishak, A.J., Shamsuddin, R. and Wan Hassan, W.Z. (2013). Ripeness level classification for pineapple using RGB and HSI colour maps. *Journal of Theoretical and Applied Information Technology*, 57(3), 587-593.

Adalgisa, B., Marzia, G., Di, L., Mario, M. and Rosalena, T. (2005). Effects of Industrial Orange Wastes on Soil Characteristics and on Growth and Production of Durum Wheat. *Agronomy for Sustainable Development, Springer Verlag/EDP Sciences/INRA*, 25(1), 129-135. https://doi.org/10.1051/agro:2004063

Agegnehu, G., Vanbeek, C. and Bird, M.I. (2014). Influence of integrated soil fertility management in wheat and tef productivity and soil chemical properties in the highland tropical environment. *Journal of Soil Science and Plant Nutrition*, 14(3), 532-545. https://doi.org/10.4067/S0718-95162014005000042

Akanbi, W.B. (2002). Growth, nutrient uptake and yield of maize and okra as influenced by compost and nitrogen fertilizer under different cropping systems, p. 228. Nigeria, University of Ibadan: PhD Thesis.

Alam, S., Mehdi Navqi, S. and Ansari, R. (1999). Handbook of Plant and Crop Stress. 2nd ed., p. 51 - 60. New York, USA: Marcel Dekker, Inc.

Alasa, J.J., Bashir, A.U., Mustapha, M. and Mohammed, 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 Journal of Engineering, Technology and Environment*, 17(4), 547-554.

Al-Sayed, H.M.A. and Ahmed, A.R. (2013). Utilization of watermelon rinds and sharlyn melon peels as a natural source of dietary fiber and antioxidants in cake. *Annals of Agricultural Sciences*, 58(1), 83–95. https://doi.org/10.1016/j.aoas.2013.01.012

Amlinger, F., Peyr, S., Geszti, J., Dreher, P., Karlheinz, W. and Nortcliff, S. (2007). Beneficial effects of compost application on fertility and productivity of soils. p. 32–75. Austria: Federal Ministry for Agriculture and Forestry, Environment and Water Management.

Baidhe, E., Kigozi, J., Mukisa, I., Muyanja, C., Namubiru, L. and Kitarikawe, B. (2021). Unearthing the potential of solid waste generated along the pineapple drying process line in Uganda: a review. *Environmental Challenges*, 2, 100012. https://doi.org/10.1016/j.envc.2020.100012

Bhatnagar, A., Sillanpää, M. and Witek-Krowiak, A. (2015). Agricultural waste peels as versatile biomass for water purification - A review. *Chemical Engineering Journal*, 270, 244–271. https://doi.org/10.1016/j.cej.2015.01.135

Cakmak, I. (2002). Plant nutrition research: Priorities to meet human needs for food in sustainable ways. *Plant and Soil*, 247(1), 3-24. https://doi.org/10.1023/A:1021194511492

Department of Agriculture (DOA). (2018). Booklet Statistik Tanaman (Sub-Sektor Tanaman Makanan). Malaysia: Department of Agriculture (DOA).

Divina, C.C. (2016). Scraps No More: Fruit Wastes for Benefits of Plants and Animals. *International Journal of Agricultural Technology*, 12(7.1), 1535-1545.

Haake, D.A. and Levett, P.N. (2015). Leptospirosis in humans. *Current Topics in Microbiology and Immunology,* 387, 65–97. https://doi.org/10.1007/978-3-662-45059-8_5

Hamad, M.E., Rimmer, D.L. and Syers, J.K. (1992). Effect of iron oxide on phosphate absorption by calcite and calcareous soils. *Journal of Soil Science*, 43(2), 273-281. https://doi.org/10.1111/j.1365-2389.1992.tb00135.x

Hikisz, P. and Bernasinska-Slomczewska, J. (2021). Beneficial Properties of Bromelain. *Nutrients*, 13 (12), 4313. https://doi.org/10.3390/nu13124313

Hindersah, R., Handyman, Z., Indriani, F.N., Suryatmana, P. and Nurlaeny, N. (2018). Journal of Degraded and Mining Lands Management Azotobacter Population, Soil Nitrogen and Groundnut Growth in Mercury-Contaminated Tailing Inoculated with Azotobacter. *Journal of Degraded and Mining Lands Management Azobacter Population*, 5(53), 2502–2458. https://doi.org/10.15243/jdmlm.2018.053.1269

Kamaluddin, M. and Zwiazek, J.J. (2004). Effects of root medium pH on water transport in paper birch (*Betula papyrifera*) seedlings in relation to root temperature and abscisic acid treatments. *Tree Physiology*, 24 (10), 1173-1180. https://doi.org/10.1093/treephys/24.10.1173

Mahmud, K.N., Yahayu, M., Sarip, S.H.M., Rizan, N.H., Min, C.B., Mustafa, N.F., Ngadiran, S., Ujang, S. and Zakaria, Z.A. (2016). Evaluation on efficiency of pyroligneous acid from palm kernel shell as antifungal and solid pineapple biomass as antibacterial and plant growth promoter. *Sains Malaysiana*, 45(10), 1423–1434.

Malakouti, M.J. (2007). Zinc is a neglected element in the life cycle of plants. *Middle Eastern and Russian Journal of Plant Science and Biotechnology*, 1(1), 1-12.

Nadzirah, K.Z., Zainal, S., Noriham, A., Normah, I., Siti Roha, A.M. and Nadya, H. (2013). Physico-chemical properties of pineapple variety N36 harvested and stored at different maturity stages. *International Food Research Journal*, 20(1), 225–231.

Olasantan, F.O. (1991). Response of tomato and okra to nitrogen fertilizer in sole cropping and intercropping with cowpea. *Journal of Horticultural Science*, 66 (2), 191-199. https://doi.org/10.1080/00221589.1991.11516144

Panwar, N. (2015). Studies on Physicochemical Characteristics and Fertility of Soil by addition of Banana Peels-Waste Management. *International Journal for Scientific Research and Development*, 3 (1), 121-125.

Parihar, P., Singh, S., Singh, R., Singh, V.P. and Prasad, S.M. (2015). Effect of salinity stress on plants and its tolerance strategies: a review. *Environmental Science and Pollution Research*, 22(6), 4056–4075. https://doi.org/10.1007/s11356-014-3739-1

Rai, N., Ashiya, P. and Rathore, D.S. (2014). Comparative Study of the Effect of Chemical Fertilizers and Organic Fertilizers on *Eisenia foetida*. *International Journal of Innovative Research in Science, Engineering and Technology*, 3(5), 12991-12998.

Reinhardt, D.H.R.C., Bartholomew, D.P., Souza, F.V.D., de Carvalho, A.C.P.P., de Pádua, T.R.P., Junghans, D.T. and de Matos, A.P. (2018). Advances in pineapple plant propagation. *Revista Brasileira de Fruticultura*, 40(6), e-302. https://doi.org/10.1590/0100-29452018302

Saito, N. and Harborne, J.B. (1983). A cyanidin glycoside giving scarlet coloration in plants of the Bromeliaceae. *Phytochemistry*, 22(8), 1735-1740. https://doi.org/10.1016/S0031-9422(00)80261-7

Sagar, N.A., Pareek, S., Sharma, S., Yahia, E.M. and Lobo, M.G. (2018). Fruit and Vegetable Waste: Bioactive Compounds, Their Extraction, and Possible Utilization. *Comprehensive Reviews in Food Science and Food Safety*, 17(3), 512–531. https://doi.org/10.1111/1541-4337.12330

Senkoro, H. (2003). Solid Waste in Africa. A WHO/AFRO perspective. CWG Workshop: Solid Waste Collection that Benefits the Urban Poor, Dar es Salaam. Rome, Italy: Collaborative Working Group (CWG) Workshop, World Health Organization African Regional Office (WHO / AFRO).

Statista. (2020). Leading countries in pineapple production worldwide in 2017. Retrieved from Satista website: https:// www.statista.com/statistics/298517/global-pineapple-production-by-leading countries.

Sutanto, A., Zen, S. and Nor, R. (2016). The Formulation of Pineapple Liquid Waste (PLW) as Liquid Organic Fertilizer for Agricultural Crops. *Scientific Journal of PPI - UKM*, 3(4), 176–181.

Tavakoli, M.T., Chenari, A.I., Rezaie, M., Tavakoli, A., Shahsavari, M. and Mousavi, S.R. (2014). The importance of micronutrients in agricultural production. *Advances in Environmental Biology*, 8 (10), 31-36.

Vasanthi. P. and Saradha Ramadas. V. (2019). Fruit Waste its Functionality and Utilization. *International Journal of Research Scientific Research*, 10, 1(F), 30677-30682.

Verdonck, O. (1997). Compost specifications. *Acta Horticulturae*, 469, 169-178. https://doi.org/10.17660/ActaHortic.1998.469.16

Viator, R.P., Kovar, J.L. and Hallmark, W.B. (2002). Gypsum and compost effects on sugarcane root growth, yield, and plant nutrients. *Agronomy Journal*, 94(6), 1332–1336. https://doi.org/10.2134/agronj2002.1332

Wunder Jr, E.A., Figueira, C.P., Santos, G.R., Lourdault, K., Matthias, M.A., Vinetz, J.M. and Ko, A.I. (2016). Real-time PCR reveals rapid dissemination of *Leptospira interrogans* after intraperitoneal and conjunctival inoculation of hamsters. *Infection and Immunity*, 84(7), 2105-2115. https://doi.org/10.1128/IAI.00094-16

Zhang, L., Li, G., Wang, M., Di, D., Sun, L., Kronzucker, H.J. and Shi, W. (2018). Excess iron stress reduces root tip zone growth through nitric oxide-mediated repression of potassium homeostasis in Arabidopsis. *New Phytology*, 219(1), 259-274. https://doi.org/10.1111/nph.15157

