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Growth and Nutrient Uptake of Roselle (Hibiscus Sabdariffa) with the Application of Organic and Inorganic Fertilisers

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ABSTRACT

Composting is a sustainable practice that uses the organic waste as the nutrient-rich compost, which offers numerous benefits in agriculture while improving soil fertility and enhances plant growth. Organic fertilisers are increasingly recognized for their potential to enhance crops productivity while at the same time have less impacts towards the environment. The aim for this study was to evaluate the effects on the different application of fertilisers on the growth and yield of the Roselle plant (Hibiscus sabdariffa) by evaluating on the plant growth parameters. This study is focused on the plant growth and determination of nitrogen (N), phosphorus (P) and potassium (K) uptake of the plant. The plants were divided into four (4) different treatments with one being the control. Among the plant growth metrics examined in this study are plant height, leaf count, and Roselle yield. After 49 days of observation, the plant height averaged at 178 mm, with 16 leaves produced across all treatments. Roselle that grown under combination of soil, fertiliser with compost (P3), and soil with fertiliser only (P4) produced the most number of fruit (8 fruits/plant). In addition, the highest leaves count (45 leaves/plant) contributed from Roselle under soil with fertiliser only (P4). It is observed that the Roselle with organic fertiliser treatment have low significant improvement in plant growth as compared to the plants in other treatments. The findings of this study showed that food waste can be applied in composting to promote plant growth ecologically responsible farming practices and improve plant development and output. The benefits of compost may be more noticeable over a longer period and in combination with other soil management practices.

Keywords: NPK uptake; organic fertiliser; plant growth; roselle

INTRODUCTION

Composting is a known sustainable approach to improve soil fertility, crop production, and environmental health in agriculture. Composting goes through multiple phases, where each stage is defined by the actions of various types of microorganisms (Gray et al. 1971). Compost, an organic fertiliser replete with essential plant nutrients, not only fosters improved soil structure and water retention but also promotes enhanced microbial activity. While being widely utilised, traditional inorganic fertilisers have the potential to harm the environment during manufacture, delivery, and usage as the usage of nitrogen containing fertilisers in large volume leads to numbers of environmental deterioration (Rahman & Zhang 2018). In contrast, organic fertilisers, characterized by their natural composition and lower nitrogen levels (Green 2015), offer a more sustainable alternative. Organic fertilisers are natural mineral sources that provide essential minerals for plants and enhance soil structure and crop development. They are safer alternatives to synthetic fertilisers.

Common organic fertilisers are decomposed organic matter from food waste and plant residues. The use of food waste as compost has gained interest due to its potential

to enhance soil fertility and sustainability. Incorporating compost into soil helps enhances soil structure by increasing organic matter (Sayara et al. 2020; Nguyen & Li 2022), significantly improves soil nutrient availability led to increased crop yields (Smith & Johnson, 2023) and using food waste compost as fertilisers will reduces landfill waste and methane emissions that supports a circular economy (Martinez & Green, 2023). However, researchers also found out few drawbacks related to organic fertilisers such as the risk of inconsistent nutrient quality in food waste compost that led to nutrient imbalances in soil (Wilson & Thompson 2023; Chen & Zhang 2024).

An opportunity to explore the production and application of food waste compost is carried out at Sekolah Kebangsaan Bukit Kemuning 2, Shah Alam or known as SKBK2. SKBK2 is one of the most active schools under the Sustainable School Program. The goal of this collaboration is to enhance the school community on the importance of the organic waste in improving soil fertility and enhancing the crop growth. Thus, this study will compare the performance of conventional and organic fertilisers for Roselles development and production, focusing on plant growth, soil quality, and nutrient uptake.

METHODOLOGY

PREPARATION OF FERTILISERS, SOIL AND PLANTS

The organic fertiliser used in this study is food waste compost consists of wastes such as eggshells, vegetables, sawdust and dried leaves that were grinded, dried, and composted in an effective microorganism (EM) anaerobic composting process. Prior to the application on the plants, the nitrogen (N), phosphorus (P), and potassium (K), content of the compost were analysed by spectrophotometry as shown in Table 1. While the inorganic fertiliser that was used is NPK 20-10-10 fertiliser that is readily available in the local nursery.

Roselle seedlings were obtained from Sekolah Kebangsaan Bukit Kemuning 2, Shah Alam where the plants were planted in polybags filled with organic soil. The plants were then transferred and planted in four different treatments, namely soil (P1), soil + compost (P2), soil + compost + NPK 20-10-10 fertiliser (P3), and soil + NPK 20-10-10 fertiliser (P4). Polyethylene bags sized 10x12 inch (width x height) were filled with cocopeat, that is going to be used as the medium for this study (Table 2). All of the plants were planted in the controlled environment of an exposure to direct sunlight for a minimum of 4-5 hours daily, with the water rate of ~500 ml per day except on rainy days.

TABLE 1. NPK content of the compost sample

Nutrient	Content (mg/L)
N	11.6
P	0.59
K	1.2

MEASUREMENT OF PLANT GROWTH PARAMETERS AND ANALYSIS OF NPK UPTAKE

The leaves and fruit of the plant were oven dried at 70°C for two (2) days, grinded, dissolved in distilled water. The sample solutions were then used for each of the nutrients analysis respectively and each of the results of the analysis were in concentrations unit (mg/L). The analysis on NPK were done by using HACH DR2800 spectrophotometer, with Persulfate Digestion Method for nitrogen, PhosVer3 (Ascorbic Acid) method for phosphorus, and Tetraphenylborate method for potassium. The uptake analysis was done at Week 1 and Week 7 of the study, and the results were compared for discussions.

RESULTS AND DISCUSSION

PLANT HEIGHT

Figure 1 shows the comparison between the plant growth condition during Week 1 and Week 7. While Figure 2 shows the height of the Roselle plants along the 49 days observation. Plants in all media shown an increment after the third week, and a gradual increase in treatment P3 and P4 onwards. The significant increase in plant height observed after applying the NPK 20-10-10 fertiliser may be attributed to the nutrient release that stimulates robust plant growth and enhances photosynthesis.

However, the plant growth in P1 and P2 came to a halt from Week 4 onwards. The slow growth in P2 can be explained by the lack of information on the carbon to nitrogen (C/N) ratio of the organic fertiliser, where an insufficient C/N ratio may result in nitrogen toxicity (ammonia), and excessively high C/N ratio can restrict growth by limiting the availability of nitrogen for protein synthesis (Mortier et al. 2016). Furthermore, the nutrient composition of compost can be uneven, leading to potential imbalances. For example, due to high nitrogen content, compost may be deficient in certain nutrients like phosphorus or potassium, which are essential for plant growth, thus can affect plant performance (Palansooriya et al. 2023).

TABLE 2. Contents for each treatment

Treatment	Content	Description
P1 (control)	Soil	650g of soil
P2	Soil + compost	500g of soil + 150g of compost
P3	Soil + compost + NPK 20-10-10 fertiliser	500g of soil + 150g of compost + 5g of NPK 20-10-10 fertiliser
P4	Soil + NPK 20-10-10 fertiliser	650g of soil + 5g of NPK 20-10-10 fertiliser

The growth rate of the compost-treated plants in this study does not align with the past studies by Syahnaz et al. (2019), and Yusuf et al. (2019) where the plants with the application of compost in this study does not have a significant change to the growth of the plants. Both studies show an exponential increase in the plant height with the application of food waste compost and goat manure, as opposed to the slow growth in the plants with the compost applied in this study. Nutrients in compost are released more slowly as the compost decomposes. This slower nutrient release can limit nutrient availability during critical growth stages (Singh et al. 2023). However, a similar increase in the plants treated with NPK 20-10-10 fertiliser can be seen from the study by Sa'id et al. (2015) on the Roselle at Samaru, Zaria, albeit at a different rate of the application used.

FIGURE 1. The plant growth and condition at Week 1 (top row), and at Week 7 (bottom row)

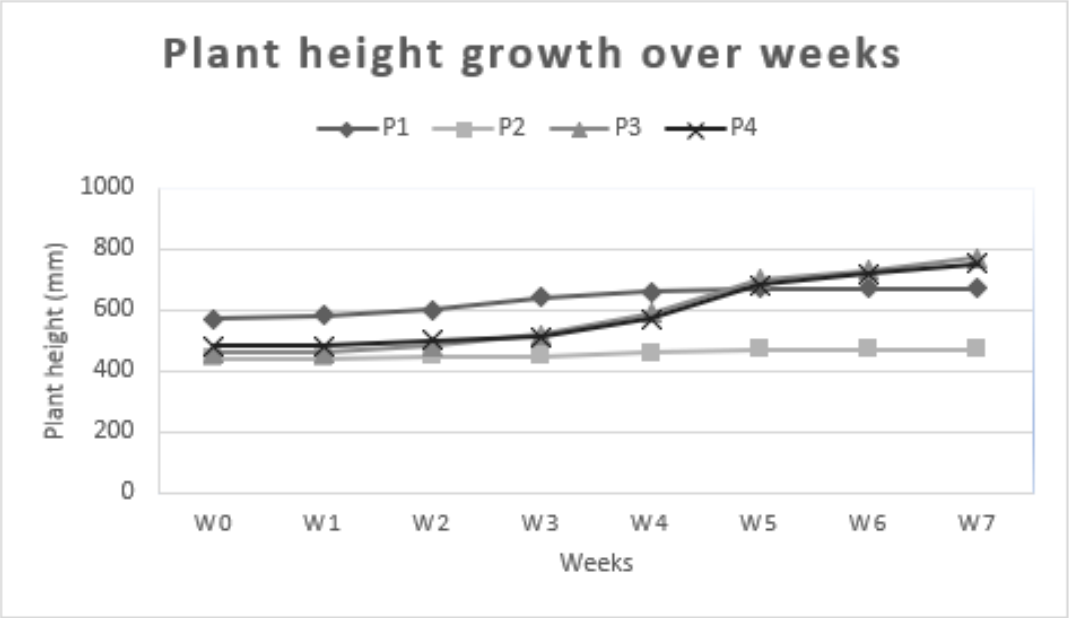

FIGURE 2. The height of the Roselle plant under different treatments.

NUMBER OF LEAVES

Leaf production is an indicator of plant development and is independent of overall plant growth. The number of leaves did vary significantly between plants that were treated with inorganic fertiliser, and the ones which are not as shown in the Figure 3. In the P1 and P2 treatment, the number of leaves shows a slight increase, and decreases in number, especially by Week 3 of the study. In contrast, P3 and P4 show a rapid increase in number of leaves by Week 4, and potentially caused by the nutrient absorption from the chemical fertiliser that boosts the nitrogen in the plant. These treatments also showing the expansion of their leaves canopy by having multiple branches across the plant and by doing so, they were able to compete more effectively for light and nutrients. The decrease in numbers of leaves recorded caused by several factors such as falling leaves, and pests as bite marks and holes were present on the leaves.

Previous study by Yusuf et al. (2019) on Roselle fertilized with goat manure on bris soil shows a similar trend of the decline in the number of leaves at later stages of growth. However, the result of this study contradicts with the past study by Syahnaz et al. (2019) on the Roselle fertilized with food waste compost that shows a steady increase in the leaves count with the application of food waste compost at the rate of 1:1. The difference in the results in these studies might be caused by the reduction of soil nutrients, soil water potential and leaves senescence (Yusuf et al. 2019). The different application rate of the applied compost should be noted, as the amount of nutrients present in the soil could differ.

YIELD OF ROSELLE

There is a significant difference between the treatments in the number of fruit yields per plant between the plants with inorganic fertilisers added and those which did not. All the plants bear fruit by the second week of the study, and the plants treated with inorganic fertiliser fruit exponentially more than the crops in the other treatments. Figure 4 shows the fruit yield of Roselle over the seven (7) weeks of observation.

As a result, after 7 weeks of the study, the crops P1 and P2 produced the most fruits (8 fruits). Because the crops treated with inorganic fertiliser began growing secondary leaves earlier, than the crops in the other treatments, they were able to create a canopy sooner and produce more fruit. Secondary leaves caused the growth of branches, resulting in extra places for fruit initiation. Conversely, the crops P1 and P2 made the slowest strides towards fruit production. According to the findings, much like with other agricultural plants, both nitrogen and phosphorus are critical for the growth and productivity of

the Roselle plant (Okosun et al. 2006). Similar to the leaves, several fruits across all plants can be seen falling on the ground that could explain on the decrease in the number of fruit yield for some plants.

Similar increase in the number of fruit yield in P3 and P4 were also reported by Sa'id et al. (2015) with the application of NPK 20-10-10 fertiliser on Roselle. The application of the NPK 20-10-10 fertiliser that is high in nitrogen content promotes the fruit development as the nitrogen is a crucial component of plant growth that is needed for the whole plant growth cycle from the vegetative stage to the harvesting stage, that allows the production of leaves and branches that ultimately increases the yield of the plants.

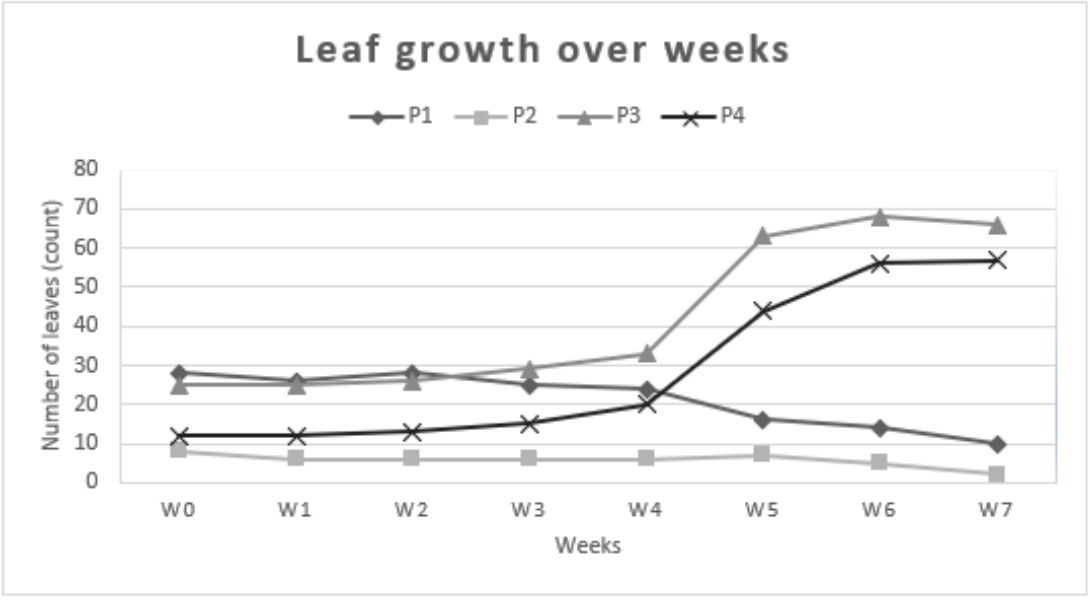

FIGURE 3. The number of leaves under different treatments

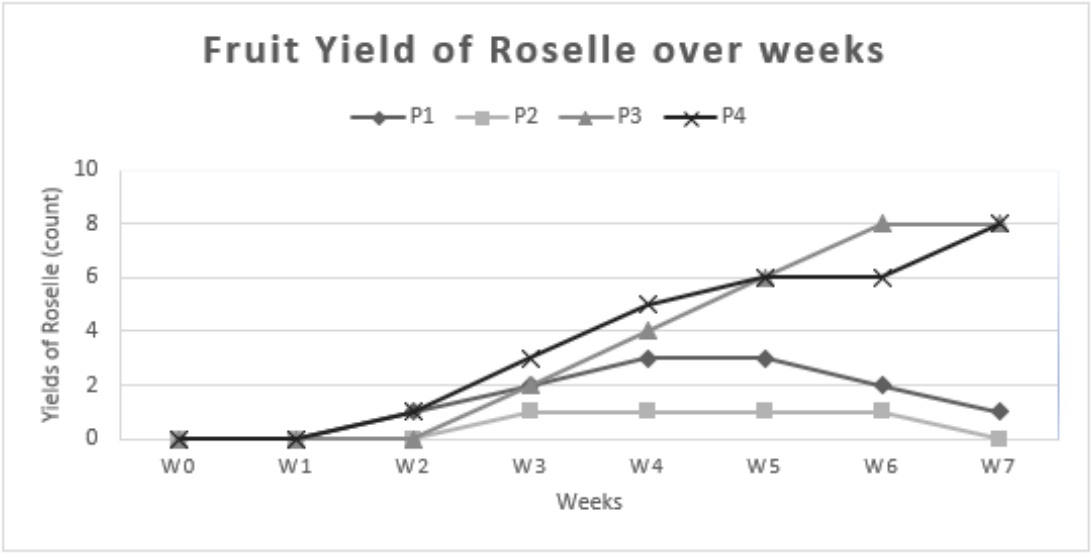

FIGURE 4. The numbers of fruits yield under different treatments.

NPK UPTAKE IN PLANT TISSUE

The effect of organic and inorganic fertiliser application on the uptake of NPK were investigated at the beginning and end of the study at Week 7 as shown in the Figure 5. The observed nutrient content for P1 at initial condition (Figure 5(a)) was 1.5 mg/L of nitrogen, 1.11 mg/L of phosphorus, and 1.7 mg/L of potassium, and ranging to the highest nitrogen concentration in P3 at 3.6 mg/L, and highest potassium in P4 at 3.6 mg/L. P1 shown an exponential increase in NPK (Figure 5(b)) at 41.2 mg/L of nitrogen, 5.54 mg/L of phosphorus and 7 mg/L of potassium despite not having added treatment to it with.

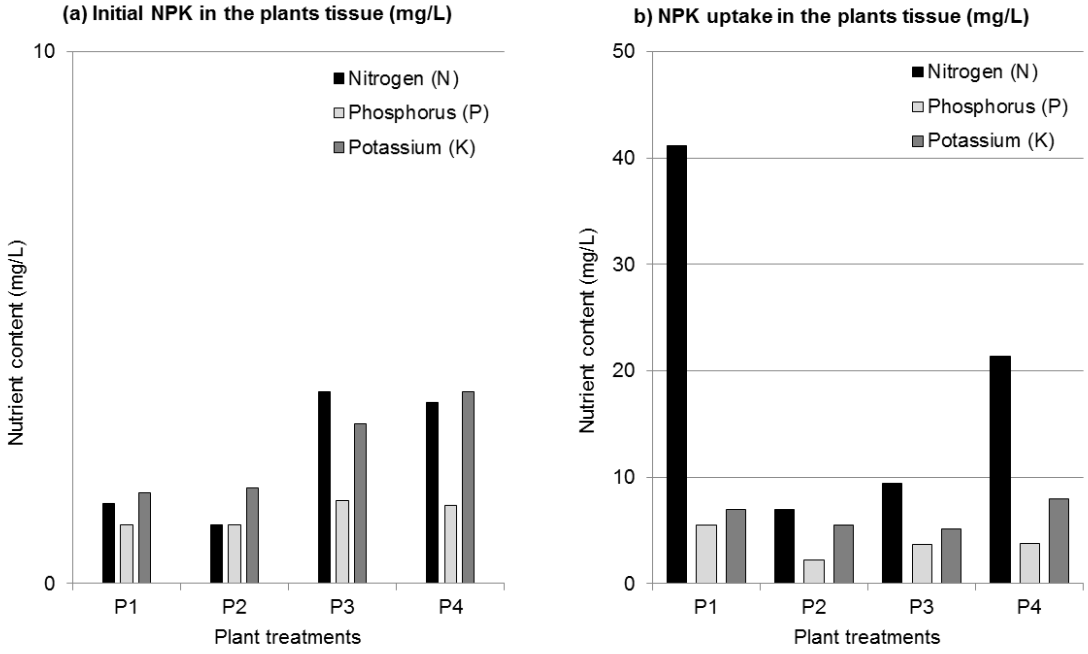

FIGURE 5. NPK uptake in the plants tissue at (a) initial, and (b) 7th week

In terms of nitrogen uptake, P2 and P3 yield an almost similar result at 7 mg/L and 9.4 mg/L respectively. It is to be expected for P4 to have a sharp increase in nitrogen uptake with 21.4 mg/L from initially 3.4 mg/L, as P4 was supplemented with NPK 20-10-10 fertiliser that is high in nitrogen content. The increase in the N, P and K uptake can be observed for all treatments, although less significant in terms of phosphorus and potassium uptake for P2. To summarize, the N, P and K uptake for P2 and P3 with the organic fertiliser treatment yielded the least uptake compared to the other plants.

The past study by Syahnaz et al. (2015) depicts a similar trend in the N, P, K content in the compost applied plants where the nitrogen content would be the highest, followed by potassium and phosphorus. Though, a different result were obtained where the plants with the applied compost in this study does not perform better than the control. As mentioned earlier in the study, the C/N ratio could affect the can cause a nitrogen toxicity in the soil, thus lowering the available nutrient in the plants tissue. The C/N ratio during the composting process can affect the rate of decomposition. The high C/N ratio, the slower the rate of decomposition due to low nitrogen. Microbes are inefficient at digesting the material due to a lack of nitrogen (Palaniveloo et al. 2020). This condition may affect the quality of the compost before it's been used for plants. Research by Ma et al. (2023) indicated that high nitrogen levels can suppress the uptake of potassium, leading to reduced stress tolerance and lower quality of crops.

There is a significant difference between the treatments in the number of fruit yields per plant between the plants with inorganic fertilisers added and those which did not. All the plants bear fruit by the second week of the study, and the plants treated with inorganic fertiliser fruit exponentially more than the crops in the other treatments. Figure 4 shows the fruit yield of Roselle over the seven (7) weeks of observation.

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NPK UPTAKE IN FRUIT

However, the same cannot be said in the terms of NPK content in the fruit yield of the Roselle. Figure 6 shows the NPK content in the Roselle fruits.

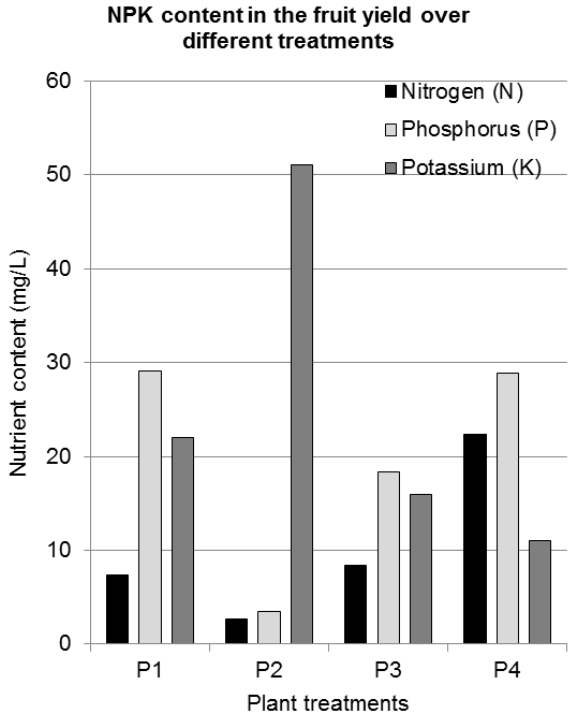

FIGURE 6. NPK content in the Roselle fruits.

P4 shows the highest amount of nitrogen in the fruit with the value of 22.4 mg/L, compared to P1, P2, and P3 with 7.4 mg/l, 2.7 mg/l, and 8.4 mg/L respectively. In terms of potassium, P content in the fruit, P2 has the highest content of P, with the concentration of 51.1 mg/L, and to be expected as the provided organic fertiliser was high in potassium content. All of these findings illustrate a contradiction that was discovered during the experiment: The plant in P1 did not absorb more nitrogen despite the high nitrogen content of the soil being accessible, and potassium content in yield in P2 have the highest concentration despite having the lowest concentration in the soil.

CONCLUSION

To achieve the objectives of this study, the organic fertiliser was applied into two treatments P2, and P3 while comparing to the control, P1 and P4 with added NPK 20-10-10 fertiliser. The growth parameters of the plants were observed and recorded every seven (7) days and compared at the end of this study. It is observed that the plants with organic fertiliser treatment have no significant improvement in plant growth as compared to the plants in other treatments. The benefits of compost may be more noticeable over a longer period and in combination with other soil management practices. An integrated nutrient management (INM) strategies is required in food waste composting method in order to mitigate soil degradation, improve crop production, and protect the environment.

In future studies, the researchers should have additional research on the stability of growing Roselle on cocopeat and performing analysis on the available nutrients in the cocopeat as compared to the soil medium and the media-specific water requirement for cocopeat. Each growing media would have a different condition, porosity, and properties. Therefore, conducting additional research on the ability of the cocopeat to support plant growth and nutrient availability is crucial for a comprehensive understanding of its suitability as a growing substrate. The compost made should also be compared to the SIRIM Standard MS1517:2012 for the parameters such as C/N ratio and allowable nitrogen content % in the compost, as well as following the guidelines in MS417 for the methods of fertiliser analysis.

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DECLARATION OF COMPETING INTEREST

None.

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