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The Effectiveness of Rice Husk Ash as Additive in Palm Oil-Based Compost in Enhancing the Nitrogen Uptake by *Brassica oleracea* var. *alboglabra* L. (Chinese Kale) Plant

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ABSTRACT

Rice husk ash (RHA), palm oil mill effluent (POME) sludge, and decanter cake can be utilized as compost to reduce environmental pollution. This research attempted to investigate the effect of RHA addition to palm oil-based compost in boosting the nitrogen (N) uptake and the growth of *Brassica oleracea* var. *alboglabra* L. (Chinese kale plant). Two categories of compost treatment were prepared in this study: Treatment 1 (control) and Treatment 2 [consisting of 10% (wt/wt) of RHA]. Both treatments were composted for 60 days until it was matured. The temperature and pH of the composts were recorded daily throughout the study. The treatments were analyzed for moisture, water-holding capacity, and nutrient content. The Chinese kale plant was grown in growing media and applied with Treatment 1 and Treatment 2 composts. The progress of plant growth was tracked every week. Based on the analysis, Treatment 2 exhibited a higher temperature and pH profile than Treatment 1. Meanwhile, the contents of N, P, and K were higher in Treatment 1 compost. However, Treatment 2 compost had higher silicon (Si) content, moisture content, and water-holding capacity. Based on the field test study carried out on the Chinese kale plant, the N uptake, and the growth of the plant, were found to be significantly higher when applied with Treatment 2 compost compared to Treatment 1 by 19% to 31% and 13% to 53%, respectively. It was proven that the addition of 10% RHA managed to provide an adequate amount of Si, moisture content, and water-holding capacity in Treatment 2

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compost that can enhance the N uptake and improve the growth of the Chinese kale plant in this study.

Keywords: Chinese kale, decanter cake, POME sludge, rice husk ash

INTRODUCTION

The increasing demand for rice in several countries, such as Malaysia, India, and China, has triggered the expansion of rice processing industries (Babaso & Sharanagouda, 2017). As rice production keeps increasing, the industry will produce the main product and waste materials. One of the valuable waste materials produced is rice husk ash (RHA). RHA is the ashes produced in abundance when the rice husk undergoes the burning process as a disposal method. According to Theeba et al. (2012), RHA contains high silica (Si) content, which makes it valuable in the agricultural industry, as it can be utilized to enhance the moisture content of the soil. Phonphuak and Chindaprasirt (2015) claimed that the presence of Si could help maintain the soil's moisture content since this element is highly porous and has a large surface area. Therefore, RHA can be applied in the composting process with other compost materials, such as palm oil mill wastes, to enhance the quality of the compost produced.

The wastes from the palm oil industry, which are palm oil mill effluent (POME) sludge and decanter cake, have been utilized in the composting process to reduce the disposal of these wastes to the environment. POME and decanter cake have contributed to the highest waste management cost in palm oil mill operations, as they contribute to a massive volume of waste. However, the utilization of the treated POME sludge can be potentially explored as it could provide sufficient essential macronutrients, such as nitrogen (N), potassium (K), phosphorus (P), and many other nutrients, to the soil and plant. Compared to other palm oil mill wastes, POME sludge is a great choice to be utilized as a biofertilizer due to its significantly high nutrient contents essential for crop growth (Sapie et al., 2019). Meanwhile, another palm oil mill waste, decanter cake, also contains high nutrient composition, making it suitable to be utilized as a bio-fertilizer. Decanter cake can be added to compost production to enhance the moisture content of the compost materials (Adam et al., 2016). RHA, together with POME sludge and decanter cake, can be utilized in the compost-making process and applied to soil to facilitate the uptake of nitrogen by the plants, especially for leafy vegetables.

For leafy vegetables, such as kale, lettuce, and cabbage, N is the macronutrient needed most for the growth of the leaves. N is normally taken by plants in ammonium form (NH_4^+) and nitrate form (NO_3^-). N is required by the plant sufficiently as this element affects various plant function levels, including plants' metabolism, growth, and development (Yousaf et al., 2021).

In Malaysia, an abundance of waste generated from the rice processing and palm oil mill industries could be potentially utilized. The disposal of these wastes, such as RHA, POME sludge, and decanter cake, can be reduced by turning them into valuable compost materials. Prior research by Hisham and Ramli (2019) discovered that the combination of POME sludge and decanter cake at a ratio of 1:1 with different percentages of RHA has proven to enhance the physicochemical properties of the compost produced. The compost produced can be applied to soil to improve the nutrient uptake by the plant and hence, promote the production of good-quality plants. Although research has been conducted to study the compost made from palm oil mill wastes, the utilization of these wastes and other organic materials, such as RHA, is worth discovering. Apart from that, current research also disregards the effect of RHA in combination with palm oil-based compost in enhancing the N uptake by the plant. Prior research by Hisham and Ramli (2019), Khairuddin et al. (2016), and Theeba et al. (2012) only covered the physicochemical properties of the compost produced from rice processing and palm oil mill wastes and not the application of these wastes on the plant.

Hence, there is a need to diversify the existing data available for the growth study related to the N uptake by the plant by applying the compost on leafy vegetables, such as *Brassica oleracea* var. *alboglabra* L. (Chinese kale) plant, which requires a high amount of N for the growth of its leaves. Therefore, the effect of RHA and palm oil-based compost can be easily observed on this vegetable. Other than that, there is a need to conduct a field test study to refine the existing data obtained by previous researchers such as Di Mola et al. (2020), Xiang et al. (2019), and Y. Wang et al. (2022), who also studied about the nitrogen uptake by leafy vegetables like Chinese kale plant. Therefore, this study attempted to investigate the effect of RHA addition to palm oil-based compost in enhancing the nitrogen uptake by the Chinese kale plant.

MATERIALS AND METHODS

Preparation of Compost

Compost preparation was prepared by adapting the same procedure used by Hisham and Ramli (2020) and Ramli et al. (2019). The rice husk ash (RHA) was acquired from a nursery in Kuantan, Pahang, while palm oil mill effluent (POME) sludge was obtained from the aerobic pond at Lembaga Kemajuan Perusahaan Pertanian (LKPP) Lepar, Pekan, Pahang. Meanwhile, the raw material for DC was collected from the oil clarification section of LKPP Lepar. This research developed two compost treatments, Treatment 1 and Treatment 2. Treatment 1 (control) consisted of 50% POME sludge and 50% decanter cake with a total weight of 5 kg. For Treatment 2 (RHA_{10}), the compost was made up of 10% RHA, 45% POME sludge, and 45% decanter cake with the same total weight as Treatment 1, as referred to the previous study by Hisham and Ramli (2020) since current work is a continuation from the previous work done in Hisham and Ramli (2019). The details of the weight composition of raw materials used in this study are tabulated in Table 1.

Table 1
Weight composition of sample preparation

Treatments	Composition of RHA added (%)	Weight of RHA (kg)	Weight of POME sludge (kg)	Weight of decanter cake (kg)	Total weight (kg)
Control	0	0	2.50	2.50	5.00
RHA_{10}	10	0.50	2.25	2.25	5.00

Note. RHA: rice husk ash; POME: palm oil mill effluent

Two containers, as illustrated in Figure 1, with a size of 16 cm (H) × 30 cm (L) × 18 cm (W), were used for composting process. The samples were allowed to be decomposed in the containers for 60 days, whereby the maturity stage was expected to achieve within this period. Throughout this period, the compost's temperature and pH were recorded daily using the AMT-300 4-in-1 Soil Survey Instrument (Microtemp Electrics, Taiwan). The matured composts were then analyzed based on physicochemical properties (moisture content, water holding capacity, N, P, K, and Si contents). The experiment was set up based on a completely randomized design (CRD), and three replicates of samples were prepared for each analysis.

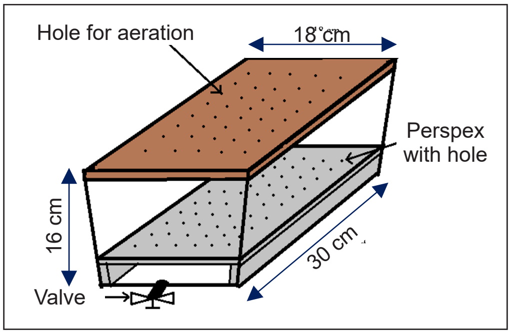

Figure 1. Illustration of composting bin

Characterization of Matured Compost

The matured composts were analyzed for moisture, water-holding capacity, and nutrient contents. For moisture content analysis, the fresh weight of the sample was measured and recorded. Then, the sample was dried for 5 hr in an oven, in which the temperature was set at 105 ± 2°C. After 5 hr, the dry weight of the sample was measured, and the standard test ASTM D4442-16 (2016) was referred to determine the percentage of moisture content.

For water holding capacity analysis, approximately 10 g of sample was mixed with 50 ml of distilled water. The sample was allowed to stand for 30 min and moved onto filter paper in a funnel. When the weight remained unchanged, the wet sample weight in the filter was measured. For every 30 min, the drop-off water was recorded until the sample began to dry. Then, the sample was oven-dried at 105 ± 2°C for 48 hr and reweighed again. Standard test ASTM D2980-02 (2002) was used to calculate the water holding capacity.

Meanwhile, for chemical analysis, the sample was dried in an oven for 24 hr at 105 ± 2°C. Then, the dried sample was pulverized using a grinder (IKA A11, Germany) to change it into powder. The micro-Kjeldahl method was performed to determine the N content. A standard method of the test using ASTM E1621-13 was utilized to determine the content of K, P, and Si by using wavelength dispersive X-ray fluorescence (WDXRF) spectrometer instrument (model Axios^{mAX}, PANalytical, Netherlands).

Field Tests and Sampling

To validate the effectiveness of Treatment 1 and Treatment 2 samples in enhancing the N uptake and plant growth, a field test study was conducted on *Brassica oleracea* var. *alboglabra* L. (Chinese kale). The experiment was based on a completely randomized design (CRD). The Chinese kale seed was germinated on a seedling tray filled with peat moss for 21 days. After 21 days, the seedlings were transferred into polybags (22.8 cm x 22.8 cm) containing cocopeat (800 g) as the growing medium. The seedlings were allowed to grow for six weeks (42 days). For analysis, the seedlings were prepared in three replications each week until they were ready to be harvested. Treatment 1 and Treatment 2 composts were applied to the plant in the first and second weeks after planting (Purbajanti et al., 2019). For analysis, the Chinese kale plant grown in the polybags was harvested weekly. The plant's fresh weight was recorded. Only the aboveground part was weighed as referred to the method described in Wijitkosum and Jiwnok (2019).

Determination of N Uptake and Crop Yield

The N uptake was investigated on the leaf part of the plant. First, the leaf part of Chinese kale was separated from the stem and roots to estimate dry matter accumulation. Next, the leaf sample was dried in an oven at 70°C until a constant weight was achieved and weighed for the dry weight (DW). The sample was then pulverized to 20 mesh and analyzed for N content using the micro-Kjeldahl method referred to as N. K. Sharma et al. (2012). The formula mentioned in N. K. Sharma et al. (2012) work was used to determine the total uptake of nitrogen.

$$Uptake\ of\ N\left(\frac{g}{pot}\right) = \frac{N\,\%\ \text{in leaf} \times dry\ weight\ \left(\frac{g}{pot}\right)}{100}$$

Equation 1

Statistical Analysis

All data obtained in this study were subjected to analysis of variance (ANOVA) by using MINITAB®18 Statistical Software (version 18.1). To determine the significant difference among means, a least significant difference (LSD) was performed at a significant level of $p \leq 0.05$, as referred to by Majbar et al. (2018) and Oviedo-ocaña et al. (2021).

RESULTS AND DISCUSSION

Temperature Profile of Compost

Temperature is an important parameter that needs to be closely monitored to determine the completion of the composting process. Therefore, the temperature profile for Treatment 1 (control) and Treatment 2 (RHA_{10}) composts were presented in Figure 2.

Based on Figure 2, the mesophilic stage was observed from day 1 to day 17. During

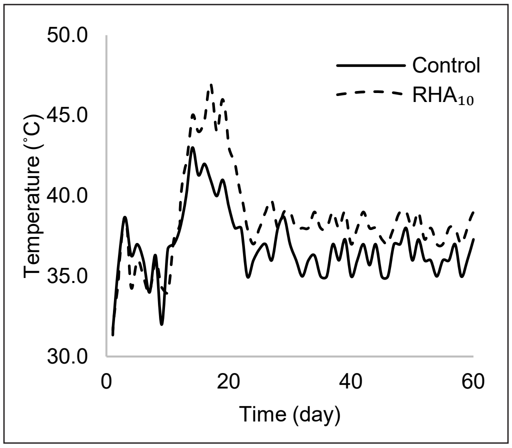

Figure 2. Temperature profile throughout the 60 days composting period

this period, the composts' temperature increased and remained within the mesophilic temperature below 45°C (Biyada et al., 2021). The highest temperature was recorded by Treatment 2 on day 17, with the temperature being around 47°C, compared to Treatment 1. The high temperature obtained by Treatment 2 might occur due to the presence of RHA in the formulated compost, which can enhance the compost's moisture content. A proper moisture content level can improve the oxygen uptake rate by aerobic microorganisms and increase microbial activity (Rastogi et al., 2020). As a result, the compost temperature would rise due to the increase in oxygen consumption and microbial activity that will generate more heat.

After the mesophilic stage, the compost temperature for Treatments 1 and 2 gradually decreased and fluctuated from day 18 until day 60. It is because the microbial activity started to slow down, though they stayed within the range of 34 to 40°C. Based on Figure 2, the temperatures fell within the range of the mesophilic stage throughout the composting period and did not enter the thermophilic stage. The thermophilic stage was not reached, probably due to the minimal microbial activity inside the composts (Hayawin et al., 2016). Moreover, although the temperature range still lies under the mesophilic stage, the stage can be identified as the curing stage based on the trend of the graph. In this stage, the compost temperature will gradually decrease until it reaches the ambient temperature, which indicates the completion of the composting process (Román et al., 2015). The matured compost can be identified based on the physical appearance of the compost, such as the black color of the material, which is almost similar to soil texture, and reduced particle size (Román et al., 2015).

pH Profile of Compost

Other than temperature, the pH of both treatments was also monitored, and the profile is illustrated in Figure 3.

Based on Figure 3, low pH values in pH 4.6 to pH 5.6 were recorded for the first ten days. Then, the pH values rose from pH 5 to pH 7. The increase in pH is due to the metabolic degradation of organic acids inside the compost (Hock et al., 2009). Other than that, it also occurred due to the transformation of N into ammonium (NH_4^+) or ammonia (NH_3) via the ammonification process (Irvan et al., 2019).

At the beginning of the composting process, Treatment 1 had a lower pH than Treatment 2 due to the original pH of the decanter cake, which was quite acidic.

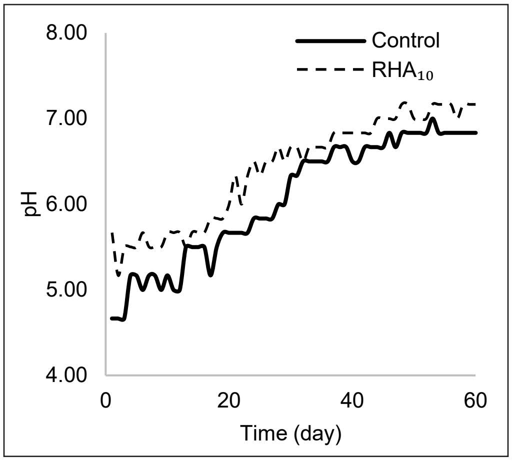

Figure 3. pH profile throughout the 60 days composting period

Meanwhile, a higher pH was obtained by Treatment 2, which might be due to the high composition of alkaline RHA. The presence of RHA in compost can ameliorate the acidity of compost; this finding has been proven by Yin et al. (2022). Eventually, the pH of both treatments reached close to a neutral level from day 45 onwards. In the composting process, the neutral pH indicates that the organic acids that exist in the compost are neutralized, which is caused by the humic substances' buffering effect, as claimed by Hock et al. (2009). According to D. Sharma et al. (2017), the final pH value between pH 6 and 8 is acceptable in composting.

Physicochemical Properties of Compost

For physical properties, the result presented in Table 2 clearly shows that Treatment 2 compost had a higher moisture content and water-holding capacity compared to Treatment 1. Meanwhile, for chemical properties, Treatment 1 contained the highest N and P contents, while Treatment 2 had the highest K and Si contents. Based on the ANOVA, the difference between the treatments was significant at $p \leq 0.05$ for all parameters.

As presented in Table 2, Treatment 2 compost had the highest moisture content and water-holding capacity, which might be due to high Si content, as referred to in the same table. According to Siddika et al. (2021), the Si content in RHA could reach as high as 90%. Si is widely used for various

Table 2
Physicochemical properties of finished composts

Parameters	Treatments (Mean ± SD)	
	Treatment 1 (Control)	Treatment 2 (RHA_{10})
Physical properties		
Moisture content (%)	47.37 ± 0.38[b]	53.21 ± 0.32[a]
Water holding capacity (%)	55.39 ± 0.85[b]	59.52 ± 0.82[a]
Chemical properties		
N (%)	3.31 ± 0.02[a]	2.97 ± 0.08[b]
P (%)	0.87 ± 0.03[a]	0.67 ± 0.02[b]
K (%)	3.46 ± 0.04[b]	3.74 ± 0.07[a]
Si (%)	18.32 ± 0.87[b]	28.12 ± 0.66[a]

Note. Means that columns with the same letters are not significantly different at $p \leq 0.05$; RHA: rice husk ash purposes for its porosity and large surface area (Lumbanraja et al., 2019). These structures allow Si to retain more water and increase the water-holding capacity of this element. As a result, the moisture content will increase as these parameters are closely related. Previous work done by Schaller et al. (2020) has proved that the soil's water-holding capacity was improved with the presence of Si since this element has an amorphous structure with a high surface area that can hold more water.

Apart from that, based on the chemical analysis result, Treatment 1 compost contained the highest N and P contents. It is because Treatment 1 had the largest weight composition of palm oil mill wastes, as shown in Table 1. Palm oil mill wastes, such as POME sludge and decanter cake, contain a substantial amount of important nutrients for plants, as claimed by Nizar et al. (2018). Therefore, these wastes contribute to the high percentage of N and P content in Treatment 1 as this treatment only contained the palm oil mill wastes without adding RHA.

Meanwhile, for K and Si contents, these elements were observed to be higher in Treatment 2 than in Treatment 1. However, the result of K content was slightly contradicted by the predicted result, whereby it was expected that Treatment 1 would have a higher K content than Treatment 2. It is because palm oil mill wastes also contain an appreciable amount of K in their composition. Treatment 2 had a lower weight composition of palm oil mill wastes, as referred to in Table 1, and supposedly, it contained a lower K content than Treatment 1. The reduction of K content in Treatment 1 might occur due to the leaching process that occurred during the composting process. K is highly soluble in water, and the availability of K inside the sample is greatly affected by leaching (Krishnan et al., 2021). Other than that, K is also a mobile ion and can be lost when K inputs surpass the soil retention capacity (Alfaro et al., 2017).

For Si content, it was found that Treatment 2 had a higher Si content compared to Treatment 2 since Treatment 2 compost contained 10% RHA composition in its components. As mentioned, RHA contained a high amount of Si in its components, which could enhance the Si content inside the compost. Moreover, work done by Hisham and Ramli (2019) also proved this finding, in which the authors discovered that adding RHA in compost production enhanced the Si content inside the finished compost.

Nitrogen Uptake and the Growth of Chinese Kale Plant

Both compost treatments were applied to the Chinese kale plant *Brassica oleracea* var. *alboglabra* L.) to validate the effectiveness of the treatments on N uptake and plant growth. The effect of N uptake on the growth of the Chinese kale plant in terms of weight is presented in Figure 4. Based on the figure, higher N uptake and weight of Chinese kale were observed on the plant that was applied with Treatment 2 (RHA_{10}) compost compared to Treatment 1 (Control).

As shown in Figure 4, the results obtained for N uptake by both treatments were significantly different since the *p*-value obtained is less than 0.05 ($p \leq 0.05$). However, high N uptake was observed on Chinese kale that was applied with Treatment 2, which could be related to the properties of high moisture content and water-holding capacity of Treatment 2 compost, as shown in Table 2. These properties of Treatment 2 compost could enhance the water availability inside the growing medium and boost the N uptake by Chinese kale grown in the medium. Water availability is crucial for plants since it carries essential nutrients from the soil to the upper parts of plants. Other than that, the presence of RHA in Treatment 2 compost enhanced the Si content in the form of amorphous silica (SiO_2), which could improve water absorption inside the growing medium.

As buttressed by Rios et al. (2017), the presence of Si in soil could regulate water uptake by the plant roots as this element was claimed to be able to promote the hydraulic conductance of the roots. Other than that, the presence of Si in Treatment 2 compost could also boost the aquaporin genes. According to Maurel et al. (2015), in most living things, aquaporin is the membrane channel that is responsible for the transport of small neutral molecules and water across the biological membrane. According to Gao et al. (2018), aquaporin genes regulate the water flow, which could regulate the movement of N

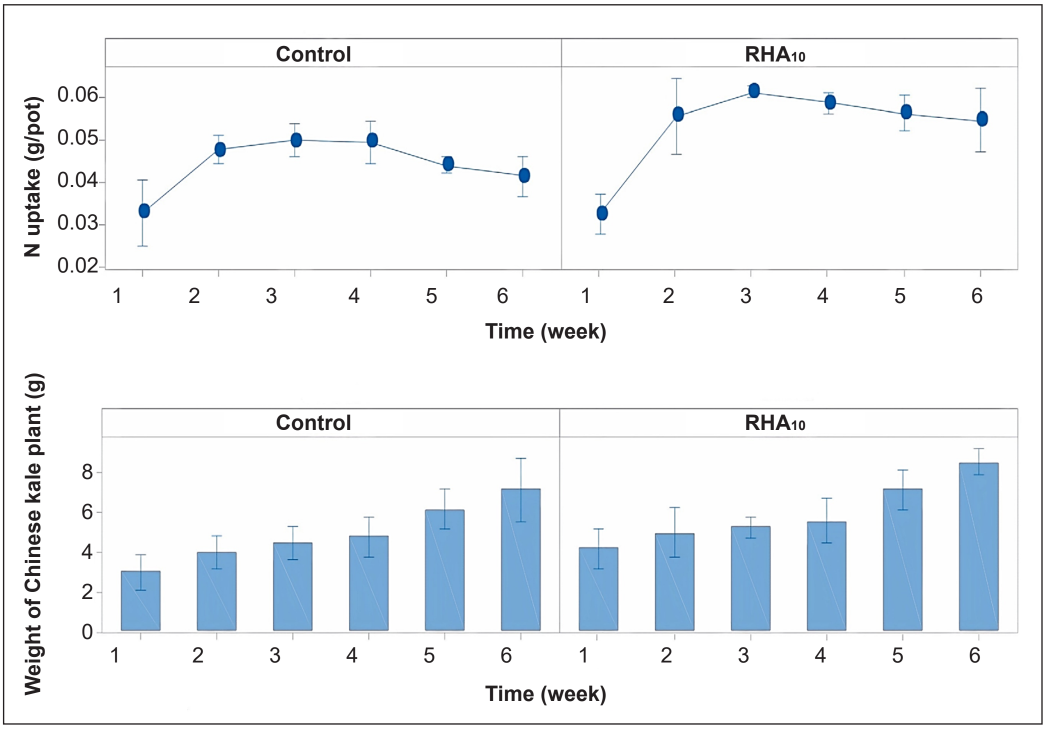

Figure 4. The N uptake and Chinese kale growth in terms of weight of plant (g) for six weeks
Note. Individual standard deviations are used to calculate the intervals

in plants. Other than that, it also plays a prominent role in N absorption and the soil's mobilization and detoxification (M. Wang et al., 2016). Hence, the sufficient amount of Si in the growing medium applied with Treatment 2 compost was proven to enhance the N uptake by Chinese kale via the role of water as the carrier of the important nutrient.

Moreover, in this study, the trend of N uptake obtained for both treatments was comparable with the work done by Onwonga et al. (2017), who also investigated the N uptake by the kale plant. The trend of N uptake by kale was claimed to have rapidly occurred at the early stage of growth since kale requires a high amount of N for the growth of its leaves. The trend will decline after reaching the maximum N uptake, indicating the growth's maturity phase. They also stated that when the growth of kale reached the maturity phase, the plant only required the N element in moderate amounts. In contrast, the uptake of other nutrients will increase. As proved in previous research conducted by Teuber et al. (2020), the increase of N uptake by kale will positively affect the biomass yield of the plant. The same correlation could be observed in Figure 2, whereby the weight of Chinese kale recorded in the growing medium applied with Treatment 2 compost was higher compared to Treatment 1 due to the high uptake of N by the plant.

Based on the result obtained for the average weight of Chinese kale, the statistical analysis indicates that the results recorded for both treatments were significantly different at $p \leq 0.05$. This finding suggests that both compost treatments significantly affected the growth of Chinese kale. By referring to Teuber et al. (2020), the availability of N strongly affects kale growth since this plant belongs to the forage Brassica species. The plant categorized in this species would require a substantial amount of N for the development and growth of its leaves. High N uptake by the leafy vegetable will enhance the photosynthetic activities and improve the conductance of stomatal and chlorophyll content (Dinh et al., 2017). As buttressed by Erwin and Gesick (2017), when the photosynthetic rate is increased, the plant's mass increases concurrently. The findings have proved that, for leafy vegetables, high N uptake is prominent in enhancing plant biomass.

Hence, the results of this work have confirmed that RHA can be utilized in composting to enhance the moisture content, water holding capacity, and Si content in the growing medium. However, in compost production, RHA is suggested to be used with other suitable compost material to enhance the nutrient contents inside the compost. The high-water content attributed to the presence of RHA is crucial in transporting important nutrients, such as N, to the leaves of leafy vegetables. High N uptake, but not excessive, will ensure plant growth is at the right trend.

CONCLUSION

This work proved that adding RHA in palm oil-based compost (Treatment 2) enhanced the temperature and pH profile during the composting process. Other than that, the presence of RHA also improves the physical properties of the compost produced. The compost needs to have a well-balanced condition of physical and chemical properties to produce high-quality compost. Treatment 2 compost has successfully improved the N uptake and the growth of the Chinese kale plant in this study due to high moisture content and water-holding capacity with a proper amount of nutrients inside the compost. It was noted in the study that the N uptake and the growth of plants applied with Treatment 2 compost were found to be significantly higher by 13% to 53% compared to Treatment 1. Overall, it is evident that applying RHA in compost production can improve the availability of nutrient-enriched water in the growing media, leading to more nutrients, especially N, being taken up by the plant for its growth.

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