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Efficacy of Compost on the Growth of Some Leafy Vegetables: A Case Study in Vietnam

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The HAL.31 is a new version of compost product of Tay Ninh Environment Company J.S.C, Vietnam. In this study, HAL.31 was compared the efficiency with an old version of organic fertilizer and inorganic fertilizer on the growth of Mustard greens, Water spinach, and Amaranth. The experiment was performed with six formulas, including NT1 (control – no fertilizers), NT2 (5 % product of the old process), NT3 (5 % HAL.31), NT4 (100 % inorganic fertilizer), NT5 (2.5 % HAL.31 and 50 % inorganic fertilizers), NT6 (3.75 % HAL.31 and 25 % inorganic fertilizers). The experiment was followed for 29 d and the data was collected every 7 d with two monitoring indicators such as tree height and the number of green leaves per tree. After 29 d, the heights of Mustard greens and Amaranth at NT3 were 10.58 cm and 19.58 cm, which were significantly different ($p \leq 0.05$) from the rest of the treatments. The data of Water spinach was 44.00 cm higher than those of the other treatments, but the difference was not significant with NT2, NT5, NT6 ($p \leq 0.05$). Similar results were recorded with the track of the number of green leaves per plant, the figures for Mustard greens and Amaranth were significantly different from the remaining treatments with 11.00 and 8.00. The data of Water spinach of 10.93 was higher than that of other treatments but was not significantly different compared to NT2, and NT5 ($p \leq 0.05$). The results showed that HAL.31 compost was completely suitable for the growth of three leafy vegetables in the study.

1. Introduction

Leafy vegetables are widely grown and consumed in tropical countries including Vietnam (Luyen and Preston, 2004). According to a report by Muriel (2003), leafy vegetables are the second most important food source in Vietnam after rice with 71.2 kg/capita/y in 2020, in which Water spinach, Amaranth, and Mustard greens are at the top position of the most common vegetable list (Muriel, 2003). Water spinach, Amaranth and Mustard greens are significant sources of protein, vitamins, and minerals (Mantovani et al., 2017). These vegetables grow in a short period, high yield, and resistant to popular insects (Christophe et al., 2019).

According to the traditional method of leafy vegetable cultivation in Vietnam, chemical fertilizers, especially nitrogen fertilizers, are key factors to achieve maximum growth and yield (Li et al., 2017). The long-term time usage of inorganic fertilizers will emerge damage to the soil, including reduced soil fertility and diversity of microbial populations, accumulation of plant toxins, soil acidification (Liu et al., 2018). Plants only absorb a part of the nutrients provided by mineral fertilizers, most of them lost to the environment and become pollutants for soil, groundwater, and surface water which cause negative impacts on human health (Cheng-Wei et al., 2014). A study by Donner and Kuchrik (2003) demonstrated more than 53 % of the N lost in corn cultivation in the Mississippi Basin.

Organic fertilizer is a broad concept that includes agricultural residue, animal manure, and compost. Compost is the product of fermentation of solid organic waste, used as fertilizer in agricultural farming, which is becoming a hot trend in the organic agricultural study (Hoang et al., 2019). The addition of organic compost not only increases the quality and yield of agricultural products, but also enriches soil fertility, improves the physical and chemical property and microecological structure of the soil, and increases microbial diversity (Parwada et al., 2020). Many composts usually have high salinity, neutral to alkaline pH, and low nitrogen content. They are not

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fully suitable for plant growth. Thus, the composts are often used in combination with inorganic fertilizers to balance the elements for plant growth. (Machado et al., 2020). Deore et al. (2010) illustrated that these used only organic fertilizer also gave positive results. The use of compost helps to reduce organic waste in landfills, reduce greenhouse gas emissions and indirectly reduce the consumption of inorganic fertilizers which reduce negative effects on the environment (Thien et al., 2021).

HAL.31 is a new version of compost which is resulted from a collaboration among Ho Chi Minh City University of Technology –VNUHCM, Center of Information and Applied Science and Technology of Tay Ninh province, and Tay Ninh Environment Company J.S.C on the basis to improve efficiency of the old composting process. The old version of compost was used anaerobic composting technology with a long composting time. Its quality was unstable and unsatisfied the Vietnam Standard for Compost Management. In contrast, HAL.31 was produced by the aerobic composting technique. In addition, some types of useful microorganisms were added to the composting process to shorten the composting time, ensure the density of beneficial microorganisms and stabilize compost quality satisfying the Vietnam Standard for Compost Management. In this study, the quality of HAL.31 was compared with the old version of compost and N – P – K fertilizer (16 – 16 – 8) through its effect on the growth of Water spinach, Amaranth, and Mustard greens.

2. Materials and methods

2.1 Experiment time and site

This study was carried out from August 2017 to October 2018 at the Center of Information and Applied Science and Technology (CIAST) of Tay Ninh province, Vietnam (11º30´44” N and 106º10’50” E). CIAST had an Experiment camp with some net houses which were used for agricultural tests on some target plants.

2.2 Growing media, seeds and fertilizers

Three types of seeds were used in this study including Water spinach, Amaranth, and Mustard greens to distribute by Phu Nong Co Ltd. Seeds are purchased and treated by soaking in warm water for 6-8 h before sowing in trays. To ensure the germination rate, the trays were regularly watered. After 7 d, the seedlings were used for the experiments. The substrate used in this study was combined from coir mulch which was treated with 5 % lime water, and rice husk ash at the ratio 70:30. HAL.31 and an old version of compost products from Tay Ninh Environment Company J.S.C, Tay Ninh province, Vietnam. N - P - K (16 - 16 - 8) was an inorganic fertilizer which was traded on Vietnam market.

2.3 Experimental design

The trails were arranged following the completely randomized design (CRD), including six treatments of different fertilizer formulations as shown in Table 1. Each treatment was conducted in triplicate.

Table 1: Six treatments formulations

Run	Formulation
NT1	Control (no fertilizers)
NT2	5 % old version of compost (25 kg/pot)
NT3	5 % HAL.31 (25 kg/pot)
NT4	100 % N - P - K fertilizer (240 g/pot)
NT5	50 % N - P - K fertilizer (120 g/pot) and 2.5 % HAL.31 (12.5 kg/pot)
NT6	25 % N - P - K fertilizer (60 g/pot) and 3.75 % HAL.31 (18.75 kg/pot)

2.4 Experimental process

The experiments were carried out in the pots with 10 m x 0.8 m x 0.3 m of dimensions (Figure 1). The substrate was mixed with fertilizers according to each formula in Table 1 and put into each pot. The seedlings with the root length of about 5 cm were transferred to experimental pots in 7th. Trail pots were placed in a net house with the mesh covering 50 % of the light. The plants were watered twice a day in the morning and afternoon. The monitoring indicators include stem height and the number of green leaves per tree. The height of the stem was measured from the position of the cotyledon to the tip of the tallest leaf using a straight ruler, and the remaining criterion was measured by calculating the number of leaves from the first true leaf to the top green leaf. The data were collected every 7 d and the experiment ended at the day 29th.

Figure 1: Experimental pots

2.5 Statistical analysis

All data from the experiments were independent of each other. One-factor analysis of variance (ANOVA) method was used to compare mean values of stem height and the number of green leaves per tree, while the Duncan test was used for multiple comparison ranges of mean values using the SPSS 16 program.

3. Results and discussions

3.1 Water spinach

Experimental results on water spinach showed that there was a significant difference between the fertilizing treatments on both plant height and the number of green leaves (Table 2). In the first 15 d, the plant height of NT2 and NT5 treatments was dramatically different from the rest of the treatments with 26.80 cm and 26.27 cm. After three weeks, plants in NT3 developed remarkably and caught up with plants in NT2, and NT5. There were without differences in plant height in NT2, NT3, and NT5 but all three treatments were significantly higher than the other treatments at the end of the test. The mean height in NT3 was 44.00 cm, which was higher than that in NT2 and NT5 with 38.89 cm and 42.22 cm.

Table 2: Height of stem and the number of green leaves results of Water spinach

Treatment's names	Stem height (cm)				Number of green leaves per tree			
	7	15	22	29	7	15	22	29
NT1	4.07^{c}	11.67^{c}	13.67^{d}	15.89^{c}	4.57^{c}	5.13^{c}	5.47^{c}	6.67^{d}
NT2	5.47^{a}	26.80^{a}	35.47^{b}	38.89^{a}	5.97^{a}	7.67^{a}	9.53^{b}	10.33^{ab}
NT3	5.33^{ab}	24.00^{b}	39.40^{a}	44.00^{a}	5.83^{ab}	7.00^{b}	10.53^{a}	10.93^{a}
NT4	4.07^{c}	10.17^{c}	17.93^{c}	29.78^{b}	4.47^{c}	4.13^{d}	5.47^{c}	7.47^{c}
NT5	5.53^{a}	26.27^{ab}	35.13^{b}	42.22^{a}	5.93^{a}	7.53^{ab}	9.07^{b}	10.40^{ab}
NT6	5.00^{b}	23.67^{b}	33.13^{b}	38.22^{a}	5.40^{b}	7.07^{b}	8.93^{b}	10.00^{b}

^{abcd}Values with different letters within in a column are significant different using Duncan's multiple rank test ($P \leq 0.05$)

Similar results were also recorded in the remaining criterion. In the first 15 d, NT2 and NT5 were the highest number of leaves to compare the rest treatments with 7.65 and 7.53, while the data of three treatments NT2, NT3 and NT5 did not have statistical difference in day 29 but the figure of NT3 was 10.93 being the highest among all treatments. In terms of morphology, plants in NT1 developed abnormally, thin, and yellow. Plants in NT4 grew slower than other treatments using compost or compost + inorganic fertilizer.

3.2 Amaranth

Plants in NT1 and NT4 were puny, stunted, and yellow. On the 7 d after transferring the plants to pots, all plants in these two treatments were dead. The remaining four treatments, plants in NT2 and NT3 which used only compost were superior growth compared to the other treatments in the first 7 d with 4.67 cm and 5.75 cm (Table 3). Plants in NT3 using HAL.31 grew faster than other fertilization treatments during the remainder of the experiment. At the last data collection time, trees in NT3 were the fastest growing with 19.58 cm, which was a significant difference from the other treatments. Plants in NT2, and NT5 were still growing, the plants were relatively weak and their heights were only 13.5 cm and 12.08 cm. NT6's plants were still alive until the 29th, but the plants grew very slowly, stunted, and yellow.

The plants in the treatments using only compost were better growth because the number of green leaves on the tree was significantly higher than that of the other treatments, in which the plants in the NT3 was the highest result than the other treatments with 5.53 leaves/plant. In the next sampling times, NT3's plants still showed a superior growth compared to the other treatments and reached the average 11.00 on day 29.

Table 3: Height of stem and the number of green leaves results of Amaranth

Treatment's names	Stem height (cm)				Number of green leaves per tree			
	7	15	22	29	7	15	22	29
NT1	0	0	0	0	0	0	0	0
NT2	4.67^{a}	6.33^{b}	8.75^{b}	13.50^{b}	4.07^{b}	5.67^{b}	7.42^{b}	8.67^{b}
NT3	5.75^{a}	9.92^{a}	12.42^{a}	19.58^{a}	5.53^{a}	8.00^{a}	9.25^{a}	11.00^{a}
NT4	0	0	0	0	0	0	0	0
NT5	1.67^{b}	3.17^{c}	7.17^{b}	12.08^{b}	2.53^{c}	5.00^{b}	6.00^{c}	8.57^{b}
NT6	2.42^{b}	2.17^{c}	3.92^{c}	8.08^{c}	3.67^{b}	3.83^{c}	4.67^{d}	6.08^{c}

^{abcd}Values with different letters within in a column are significant different using Duncan's multiple rank test ($P \leq 0.05$)

3.3 Mustard greens

Similar to the experiment result on Amaranth, trees in NT1 and NT4 grew slowly, stunted, and yellow when moved from the sowing trays to the experimental pots. Finally, all plants in two treatments died before the first data collection (Table 4).

Table 4: Height of stem and the number of green leaves results of Mustard greens

Treatment's names	Stem height (cm)				Number of green leaves per tree			
	7	15	22	29	7	15	22	29
NT1	0	0	0	0	0	0	0	0
NT2	4.75^{a}	7.08^{a}	7.83^{a}	8.50^{b}	4.75^{b}	5.89^{a}	6.58^{a}	7.33^{b}
NT3	4.75^{a}	5.17^{b}	7.92^{a}	10.58^{a}	5.17^{a}	5.56^{a}	6.67^{a}	8.00^{a}
NT4	0	0	0	0	0	0	0	0
NT5	4.58^{a}	5.92^{b}	6.33^{b}	6.33^{c}	4.75^{b}	5.89^{a}	5.91^{b}	7.00^{b}
NT6	2.75^{b}	3.42^{c}	4.25^{c}	4.75^{d}	3.67^{c}	5.89^{a}	5.91^{b}	6.00^{c}

^{abcd}Values with different letters within in a column are significant different using Duncan's multiple rank test ($P \leq 0.05$)

Until day 15, plants in NT2 (used the old version of compost) were significantly higher growth than the other treatments with 7.08 cm, followed by NT5 with only 5.92 cm. The data at the 3rd sampling time showed that the plants in the NT3 were a faster growth rate and caught up with the plants in the NT2. At the end of the experiment, plants in NT6 were the worst growth (4.75 cm) with yellow leaves and thin stems, while NT5 plants grew better (6.33 cm) but still lower than that of the rest treatments used only compost. Plants in both NT2 and NT3 treatments grew well, but plants in NT3 grew dramatically better with 10.58 cm compared with 8.50 cm in NT2.

Using only compost also had a positive effect on the number of green leaves on the plant compared to using a combination of compost and inorganic fertilizer. During the experiment, the number of leaves per tree of NT2 and NT3 was always significantly higher than that of NT5 and NT6. However, the NT3 treatment was the highest data with 8.00, which was significantly different from the rest of the treatments at day 29.

4. Discussions

Organic fertilizers' supplementation had a positive effect on the growth of Water spinach, Amaranth, and Mustard greens. All treatments that the applying composts had superior growth compared to the control and the treatment that used only inorganic fertilizer, in which the treatment using HAL.31 gave the best results. The HAL.31 fertilizer helped water spinach plants to increase by nearly 180 % and 48 % in height compared to the control and strictly using only inorganic fertilizers (44.00 cm compared with 15.89 cm and 29.78 cm). Similar results were observed in Amaranth and Mustard greens. These results lined with the results of previous studies by Liu et al. (2018) and Cheng-Wei et al. (2014) illustrated to impact of organic fertilizers and inorganic fertilizer on the growth of Spinach and Lettuce. For leafy vegetables, nitrogen (N) was an important factor for fast growth and high yield on leafy vegetables (Shah et al., 2016). Organic fertilizers contain a lot of organic N and slowly release to provide for plants, this was caused that using organic fertilizers often grow slowly in the early stages but will grow faster in the later stages (Machado and Serralheiro, 2017). Applying organic fertilizers helped to improve the physical and chemical properties, change the microecological structure and increase the N holding capacity of the soil (Chang et al., 2008).

The treatment using NT3 (using only HAL.31) gave the best results both in terms of height and the number of green leaves compared to other tests in all using compost treatments. These results showed that the quality of HAL.31 was improved which was compared to the old version of compost. Many previous studies showed that the combination of organic and inorganic fertilizers helped the plant to grow better and achieve higher yields (Zhang et al., 2020). The results were completely opposite with these researches when only using HAL.31 without inorganic fertilizer gave superior results compared to the treatments with the addition of inorganic fertilizer. These demonstrated that HAL.31 supports the vegetables to grow well without the addition of mineral fertilizer, towards sustainable vegetable cultivation and reduces the environmental impact caused by the overuse of inorganic fertilizers.

The results of NT2 and NT3 treatments on Water spinach and Mustard greens showed that plants in the NT2 treatment grew faster than those on NT3 treatment before 21 d. However, plants in NT3 treatment grew significantly well at the later period. The HAL.31 was not better than the old version of compost at the early stage but it supported the plants to grow better until the end of the experiment (Fernandez-Bayo et al., 2018). This result demonstrated that HAL.31 was richer nutrient and more stable than the old version of compost. Plants in NT1 and NT4 treatments showed slow growth, most of them were very small and a yellowish color. In Amaranth and Mustard greens experiments, all trees died before the date of first sampling. This illustrated that the growing medium which was used in the study was very poor nutrients, plants in NT1 were not provided nutrients to grow and chlorophyll synthesis due to nitrogen deficiency (Machado et al., 2020). These results demonstrated that the nutrients provided to plants in the experiments were mainly supplied by compost or chemical fertilizer. The use of 100 % N - P - K in NT4 could cause over-mineral syndrome and toxic to plants (Shaheen et al., 2014).

5. Conclusion

Leafy vegetables are one of the most important vegetables in Vietnam as well as in other tropical countries, in which Water spinach, Amaranth, and Mustard greens are at the top position of the list. Fertilizes such as compost, organic, inorganic fertilizer are essential factors for growth of leafy vegetables. Thus, selection of a suitable fertilizer is important in farming of these vegetables. In this study, the new compost version HAL.31 was demonstrated to significantly improve the growth of Water spinach, Amaranth, and Mustard greens compared to an inorganic fertilizer or a combination of the organic and inorganic fertilizer. The quality and stability of the HAL.31 has been improved compared to the old version of the compost. The usage of compost not only increases the quality and yield of vegetables, but also improves the physical and chemical property and microecological structure of the soil. Since the high efficiency of the HAL.31 is shown in this study, it is expected to widely use in cultivation of leafy vegetables on the farms.

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