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Effect of Organic Waste Fertilizers on Growth and Development of Okra (*Abelmoschus esculentus*)

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ABSTRACT

Okra (*Abelmoschus esculentus*) is an important vegetable crop grown with high demand and economic value. Thus, to improve the growth and development of okra, organic fertilizer can minimize inorganic fertilizer usage. The experiment was carried out in a greenhouse for 6 weeks to compare the growth rate of okra between a combination of organic waste fertilizers and NPK fertilizer and to determine the most suitable organic waste fertilizer combination with NPK fertilizer for the growth and development of okra. The experiment was laid out in a randomized complete block design (RCBD) with 4 replications consisting of 5 treatments, where T0: no fertilizer, T1: NPK 12:12:17:2 (20 g), T2: NPK 12:12:17:2 (10 g) + vermicompost (25 g), T3: NPK 12:12:17:2 (10 g) + biochar (25 g), T4: NPK 12:12:17:2 (10 g) + chicken manure (25 g), respectively. Parameters assessed were plant height, number of leaves, chlorophyll content, number of fruits, fresh and dry weight, and soil pH. Results indicated that the growth and development of okra were significantly the lowest in T0 and T1 while the highest in T4. Okra in T4 showed the best performance by achieving the highest value for all parameters assessed after 6 weeks of planting. It can be deduced that NPK 12:12:17:2 (10 g) + chicken manure (25 g) might be the most suitable fertilizer combination to promote the higher growth of okra while reducing the dependency on inorganic compound fertilizers.

Keywords: Biochar, chicken manure, NPK 12:12:17:2, okra, organic waste fertilizer, vermicompost

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INTRODUCTION

In many developed countries, the vegetable crop has been the most important food resource for human livelihoods. Moreover, vegetable farming has become important in fulfilling the world's population growth rate requirement since it has become a vital food for nutrient supply. Okra (*Abelmoschus esculentus*) is an important and profitable vegetable crop grown from the Malvaceae family and cultivated in many countries, including Asia, Africa, southern Europe, America, and the Indo-Pak subcontinent (Kumar et al., 2013). Production of okra in the world is estimated at 6 million tons/year, and the production has risen over the years, with India estimated at 67.1% of the total world production, followed by Nigeria being 15.4% and Sudan at 9.3% (Sorapong, 2012).

Okra, or ladies' finger or *Bendi* in Malaysia, is popular due to its healthy aspects, such as high fiber, antioxidants, vitamin C, minerals, potassium, and calcium. It is also important in tropical and subtropical countries as a medicinal plant for plasma replacement (Kumar et al., 2013; Sorapong, 2012). Okra is popular due to its short production time and easy growing, and it is a multipurpose plant for its numerous uses for its fresh leaves, flowers, buds, pods, stems, and seeds. Furthermore, okra's potential for medicinal value has been recognized (Gemede, 2015). Okra mucilage can be used as a blood volume expander or plasma replacement for medical purposes. The okra's mucilage binds the cholesterol and toxins in bile acid will be excreted by the liver, and mostly the whole part of the okra is fit to eat and used for food (Gemede, 2015; Maramag, 2013).

The fertilizer requirement is important at early growth to increase okra's productivity and quality. Currently, chemical fertilizer such as NPK (nitrogen, phosphorus, and potassium) is widely used in agriculture, including in vegetable crop planting, as it results in high productivity in a short time. However, it is quite expensive and results in nutrient imbalance and soil acidity (Akande et al., 2010). Applying organic manure has shown a positive response by increasing soil microbes and plant health. Manures are frequently applied at a higher rate than inorganics. High rates have residual impacts on crop development and production. In many countries, combining organic and inorganic fertilizers may be helpful and relative to applying each material separately. As such, the combination usage of powdered rock phosphate and chicken manure considerably boosted the growth and development of okra (Akande et al., 2004). Hence, mixing compost, manure, and biochar with inorganic fertilizer could enhance plant growth. Therefore, the organic application may produce eco-friendly and sustainable okra farming. The combination of different organic waste fertilizers may ameliorate the high dependency on chemical usage while reducing the cost of inorganic fertilizers and improving the growth development and productivity of okra. Apart from improving crop output, the approach has a better residual effect than using organic or inorganic fertilizer alone (Akande et al., 2010).

Therefore, the objectives of this study were to compare the growth rate of *A. esculentus* between the combination of organic waste fertilizer and NPK fertilizer as well as to determine the most suitable organic waste fertilizer combination with NPK fertilizer for the growth and development of *A. esculentus*. Comparing the different types of organic fertilizer can determine which organic waste fertilizer combinations have high growth rates and are most suitable as an alternative to reduce the dependency on inorganic fertilizer usage. This research also focuses on reducing the use of inorganic fertilizer in crops that negatively impact soil, the environment, and human health. Intensive use of inorganic fertilizer can be reduced by mixing both inorganic and organic fertilizers.

MATERIALS AND METHODS

Experimental Materials

This experiment was conducted in a greenhouse of Universiti Teknologi MARA (UiTM) Jasin Campus, Melaka, Malaysia (2°13'44.0" N 102°27'30.7" E). The experiment was held for 2 months, from November 2021 to December 2021. Since this experiment was done in the greenhouse, hence the microclimate in the greenhouse was as follows: temperature of 32 ºC, sunshine or more than 5.5 hours/day with more than 17 MJ per sq m per day, relative humidity of 80%, and mean wind speed of 10m/sec.

The experiment was conducted using certified okra seed from Leckat Brand (Malaysia) of F1 Hybrid Indian Ocean 535. Before planting, okra seeds were soaked overnight in a container filled with water to hasten the germination rate by softening the outer layer of okra seed. The planting of the okra seeds involved a transplanting method where the seeds were sown on germination trays filled with peat moss as planting medium during the initial stage. After 7 to 10 days, the seedlings started emerging with at least one true leaf where they were ready for transplant into a large polybag of 10 kg of topsoil (14" × 14").

The topsoil used in this study was a clay loam of Malacca series (Typic Hapludox) from a cultivated field in the Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA Agricultural Farm at Merlimau, Malacca. The soils were taken at 0–15 cm depth. Soil pH was determined on a 1:2.5 soil: distilled water suspension using a glass electrode (Peech, 1965). Soil texture was determined using the hydrometer method (Tan, 2005). Soil organic matter (SOM) content was determined by the loss-on-ignition method after placing samples in a muffle furnace at 300–550 °C for five hours (American Society for Testing and Materials [ASTM], 1988). The percentage of organic carbon is assumed to be 58% of the organic matter content. Bulk samples (undisturbed) were also collected for bulk density determination using stainless steel rings (diameter 5.2 cm, height 6.0 cm).

Treatment Application

The organic waste fertilizers used were chicken manure, vermicompost, and biochar, while for inorganic fertilizer, NPK (Mg) 12:12:17:2 (Twin Arrow Fertilizer, Malaysia) was used. The number of fertilizers applied to each polybag was about 20 g of NPK 12:12:17:2 (T1), as recommended by the Department of Agriculture (DOA) (1997).

For other treatments, NPK 12:12:17:2 was integrated with organic waste fertilizers (Dsyira Enterprise, Malaysia), which were 25 g of vermicompost (T2), 25 g of biochar (T3), and 25 g of chicken manure (T4), respectively as shown in Table 1. Previous research referred to the rate of organic waste fertilizer use (Premsekhar & Rajashree, 2009; Sarma & Gogoi, 2015).

The organic waste fertilizers were applied into the soil one week before transplanting as recommended by DOA (1997), as organic amendments need to undergo decomposition before being able to release nutrients (N, P, K, and Mg) required by the plants (Chandini et al., 2019), where the organic waste fertilizers were mixed with soil to avoid from settling in one spot and ensuring uniform application and nutrient release as to allow the microbial activity to work and to improve the soil properties (Uka et al., 2013). Alternatively, the application for NPK 12:12:17:2 was conducted at week 2 and week 6 after transplanting that was applied 6-7cm away from the plant's collar to prevent the plant from scorching (DOA, 1997). Watering was done manually twice per day (1 liter/polybag). This study involved 5 treatments with 4 replications using a randomized complete block design (RCBD) (Table 1).

Table 1
Treatments used in this experiment

Treatment	Description
T0	No fertilizer
T1	NPK 12: 12: 17:2 (20 g)
T2	NPK 12: 12: 17:2 (10 g) + vermicompost (25 g)
T3	NPK 12: 12: 17:2 (10 g) + biochar (25 g)
T4	NPK 12: 12: 17:2 (10 g) + chicken manure (25 g)

Collection of Data

Okra was harvested about 2 months after sowing. In this study, the parameters for the growth and development of okra that were measured to determine the effect of the treatments were plant height, number of leaves, chlorophyll content per leaf, number of fruits, soil pH, as well as fresh and dry weight of plants. The plant height was measured from the surface of mineral soil up to the highest tip of the plant using a measuring tape. The number of leaves per plant was measured by counting the leaves after the true leave emerged. The chlorophyll content in leaves was measured using Soil Plant Analysis Development, SPAD-502 meter (Konica Minolta, Japan). The meter was calibrated for around 15 minutes before taking readings correctly. Soil pH measurement was using a pH meter at a 1:2.5 soil-to-solution ratio (Enio et al., 2021). All the measurements stated above were recorded and collected every 2 weeks. In addition, a number of fruits were collected and recorded when the plant started to develop fruits. Finally, the fresh weight of the plant was measured by using the electronic balance in the laboratory right after harvesting the plant. In contrast, the dry weight of plant shoot and root was measured by using electronic balance after harvesting and underwent a drying process in the drying oven at approximately 60 °C for 5-7 days after a constant weight was achieved.

Statistical Analysis

All the data was collected and recorded in the statistical package for social science (SPSS) (version 21) using analysis of variance (ANOVA) software to determine if there are any significant differences between the treatments. The mean data of the treatments were compared using Tukey's test. The significant difference was considered at $p < 0.05$.

RESULTS AND DISCUSSION

Soil Physical and Chemical Characteristics

The selected chemical properties of the soil, as shown in Table 2, were typical of Malacca Series and were consistent with those reported by Paramananthan (2000). Therefore, the pH and organic matter content were considered low, typical for such a series. According to Paramananthan (2000), soils of the Malacca series are lateritic soils, which contain high iron and aluminum while low in cation exchange capacity (CEC) and water holding capacity, thus explaining the low pH and organic matter content.

Table 2
Selected physical and chemical characteristics of topsoil used in this study

Characteristics	Values
pH	4.2
Sand (%)	35
Silt (%)	38
Clay (%)	33
Organic matter (%)	0.74
Organic carbon (%)	0.43
Bulk density (g cm^{-3})	1.4

Effect of Treatments on Plant Height in *Abelmoschus esculentus*

Figure 1 shows the effect of different treatments on the okra plant height (*Abelmoschus esculentus*) during 8 weeks of growth. During the initial week (week 2), the plant height in each treatment showed no significant differences. However, the plant started showing response to the treatments from week 6 onwards as T4 (NPK 12:12:17:2 10 g + chicken manure 25 g) showed the highest plant height (43.85 cm) significantly at week 8, followed by T3 (NPK 12: 12: 17: 2 10 g + biochar 25 g) with 34.65 cm in height, T2 at 25.83 cm in height while the least was found in T1 (NPK fertilizer alone) with only 19.18 cm in height at 8 weeks of plant growth after transplanting.

From week 4 to week 8, treatments added with organic waste fertilizers resulted in significant plant height ($p < 0.05$). It could be attributed to the organic wastes (vermicompost, biochar, and chicken dung) ability to improve soil fertility as a result of decomposition, and these waste materials may have released both macro and micronutrients necessary for plant growth while also improving the soil's physicochemical properties (Tiamiyu et al., 2012), thus justifying the increase in plant height. It can also be observed from Figure 1 that okra treated with poultry manure in T4 performed better than other organic fertilizers implying that decomposition in chicken manure might be more rapid due to its lower C: N ratio (Adekiya et al., 2020) and thus nutrients in such manure

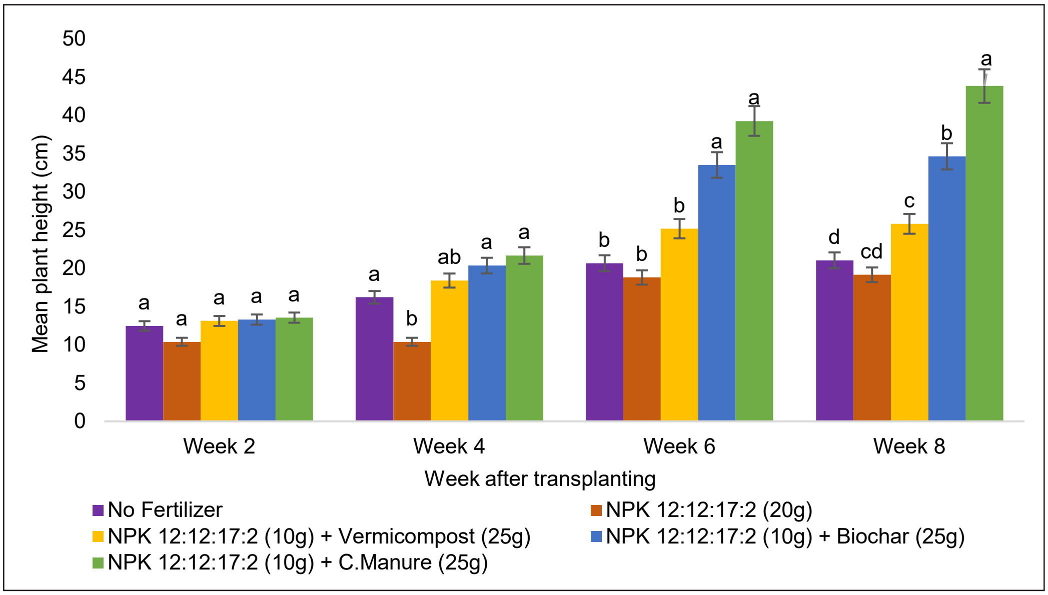

Figure 1. Effect of treatments on plant height of *Abelmoschus esculentus* during 8 weeks of growth
Note. Small letters display mean separation between treatments for a particular week using Tukey's test at a 5% level. Different letters are significantly different between treatments applied for the particular week.

was more readily available and in the optimal amount for root to absorb easily, thus explaining accelerated performance in plant height (Tiamiyu et al., 2012). Such observation agreed with the findings by Adekiya et al. (2020), Ajari et al. (2004), and Olaniyi et al. (2010) that poultry manure increased the height of okra relative to other amendments. Therefore, the superior N supply by poultry manure during okra cropping in this experiment may be the reason for the better growth and yield of okra in plots with chicken manure.

Effect of Treatments on Number of Leaves in *Abelmoschus esculentus*

The effect of treatments on the number of leaves in okra was similar to the result in plant height, whereby the response towards the treatments was more prominent from week 6 onwards, as shown in Figure 2. Therefore, it can be observed that, generally, there were no significant differences between all treatments during weeks 2 and 4. However, at week 6, the number of leaves showed significant differences between treatments applied where T4 was found to contain the highest number of leaves (8.5 leaves), followed by T3 (6 leaves) and T2 (4 leaves), while the least number of leaves was found in T1 with only 2 leaves.

The number of leaves in week 6 for all treatments was higher compared to week 8 due to the leaves started to fall off. The increase in the number of leaves per plant caused by organic fertilizer treatment emphasized the necessity of organic fertilizer during plant vegetative growth (Tiamiyu et al., 2012). Majanbu et al. (1986) found that N and K are the most

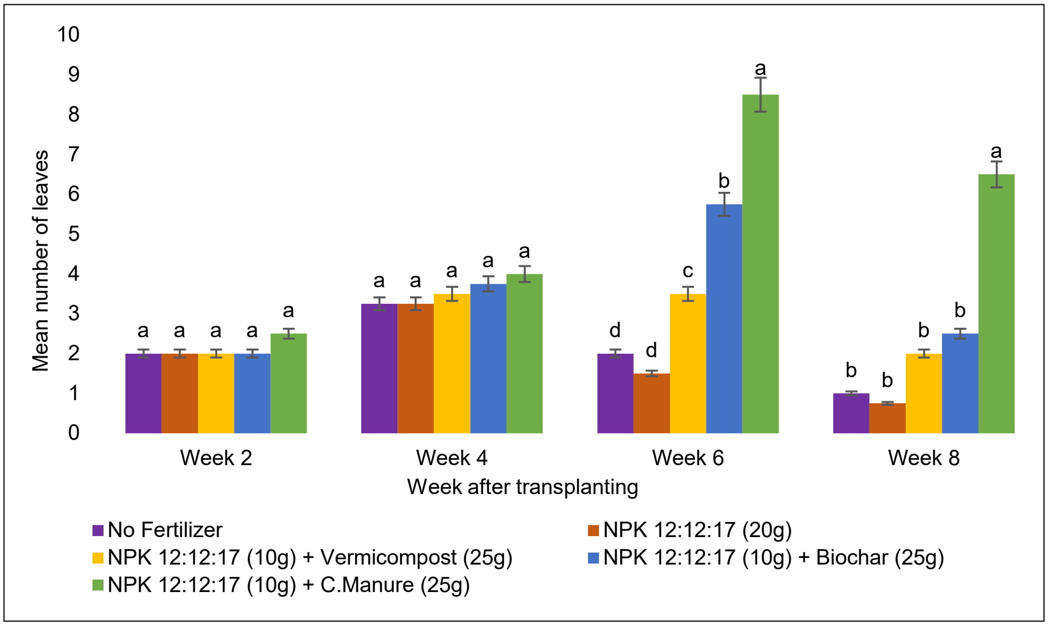

Figure 2. Effect of treatments on the number of leaves in okra (*Abelmoschus esculentus*) during 8 weeks of growth
Note. Small letters display mean separation between treatments for a particular week using Tukey's test at a 5% level. Different letters are significantly different between treatments applied for the particular week.

important macronutrients that okra required for proper growth and pod production and that chicken manure is known to have high concentrations of N and P as well as low carbon: nitrogen (C: N) ratio. Also, nitrogen is well known to be the major constituent of chlorophyll, protein, amino acids, various enzymes, nucleic acids, and many other compounds in the cell of plants (Agbede, 2009). Hence, the relatively high nitrogen concentration of chicken manure promotes crop vegetative growth and thus increases the number of leaves. According to Uka et al. (2013), organic fertilizer had a good influence on vegetative development. Moreover, okra grown on chicken manure outperformed other organic soil amendments and NPK fertilizers in terms of growth and yield. These characteristics of poultry manure result in rapid mineralization and early nutrient release in a short gestation crop like okra, increasing morphological growth such as the number of leaves (Adekiya et al., 2020).

Effect of Treatments on Chlorophyll Content in *Abelmoschus esculentus*

Figure 3 displays the mean for chlorophyll content (µg cm^{-2}) as affected by the different treatment applications starting from week 4 to week 8. In general, it can be observed that throughout the weeks, treatment with organic waste fertilizer resulted in significant chlorophyll content ($p < 0.05$), where chlorophyll content was significantly the highest in T4 (NPK 12:12:17:2 10 g + chicken manure 25 g), which was 78.68 µg cm^{-2}, followed by T3 (NPK 12:12:17:2 10

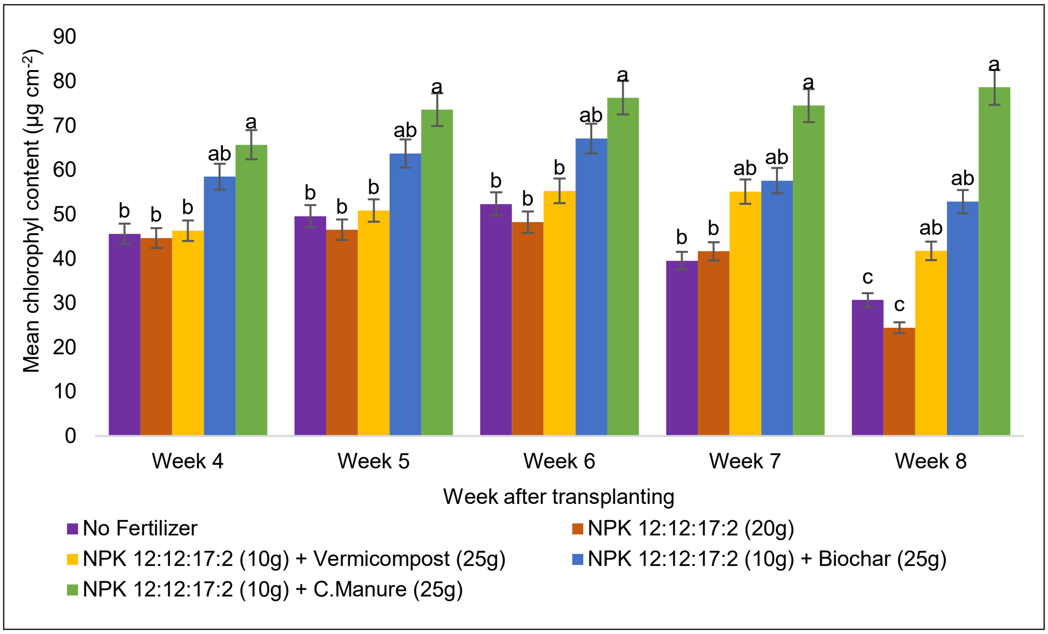

Figure 3. Effect of treatments on chlorophyll content in okra (*Abelmoschus esculentus*) during 8 weeks of growth

Note. Small letters display mean separation between treatments for a particular week using Tukey's test at a 5% level. Different letters are significantly different between treatments applied for the particular week.

g + biochar 25 g) containing 52.88 µg cm^{-2}, T2 (NPK 12:12:17:2 10 g + vermicompost 25 g) recorded about 41.75 µg cm^{-2}, T0 (no fertilizer) which was 30.7 µg cm^{-2}, and the lowest mean of chlorophyll content was observed in T1 (NPK 12:12:17:2 20 g), which recorded about 24.45 µg cm^{-2}. The use of an organic source of nutrients may have greatly increased the chlorophyll content in the leaves (Premsekhar & Rajashree, 2009). Also, since the number of leaves was greatly affected by the application of treatments, the amount of total chlorophyll content in the plant was also increased as the total number of leaves increased.

One of the most important biomolecules is chlorophyll, critical for photosynthesis, allowing plants to get energy by absorbing sunlight (Khandaker et al., 2017). The increased use of organic manures, which contains significant amounts of magnesium, may have benefited chlorophyll synthesis, increasing the rate of photosynthesis (Premsekhar & Rajashree, 2009). In addition, the magnesium in organic fertilizer is involved in chlorophyll production, which will increase the rate of photosynthesis. Furthermore, the application of organic manures would have helped the metabolic activity of plants by supplying essential micronutrients during the early stages of robust growth (Premsekhar & Rajashree, 2009). According to Khandaker et al. (2017), the amount of chlorophyll varies depending on the factors of edaphic and climatic conditions, such as water and light stress and fertilizer as well as depending on the phase of the vegetation cycle.

Effect of Treatments on Number of Fruit in *Abelmoschus esculentus*

Figure 4 displays the mean number of fruits affected by treatment applications for weeks 5, 6, 7, and 8. The application of chicken manure with NPK fertilizer (T4) significantly showed the highest number of fruits in *A. esculentus,* which was 4, followed by T3 (NPK 12:12:17:2 10 g + biochar 25 g), which was 2.5, T2 (NPK 12:12:17:2 10 g + vermicompost 25 g) which is 1.5. Conversely, the lowest number of fruits was in T0 (No fertilizer) and T1 (NPK 12:12:17:2 20 g), which was 1.

Animal manures, when handled efficiently, promote long-term agricultural productivity by immobilizing nutrients that are prone to leach. Nutrients in manure are released more slowly and are kept in the soil for a longer period, resulting in longer residual effects, increased root development, and higher crop yields (Akande et al., 2010). Besides that, the response of high yield due to organic fertilizer is attributed to the improvements in soil's physical and biological qualities, which resulted in increased nutrient availability and improved crop growth and production (Premsekhar & Rajashree, 2009).

Effect of Treatments on Fresh and Dry Weight in *Abelmoschus esculentus*

Figure 5 displays the mean fresh and dry weight (g) as affected by treatment applications, where it can be observed that no significant differences were observed between T0, T1, T2, and T3. It was only in T4 where the weight was significantly different from other treatments and showed the highest mean of fresh and dry weight, 59.29 g and 9.08 g, respectively. The increase in fresh weight of okra with the

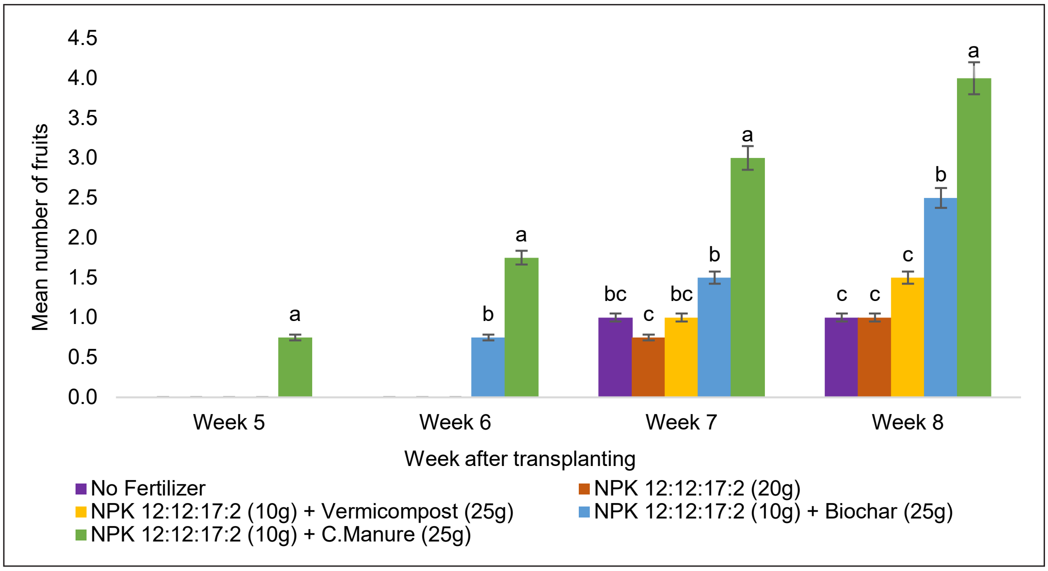

Figure 4. Effect of treatments on a number of fruits in okra (*Abelmoschus esculentus*) during 8 weeks of growth
Note. Small letters display mean separation between treatments for a particular week using Tukey's test at a 5% level. Different letters are significantly different between treatments applied for the particular week.

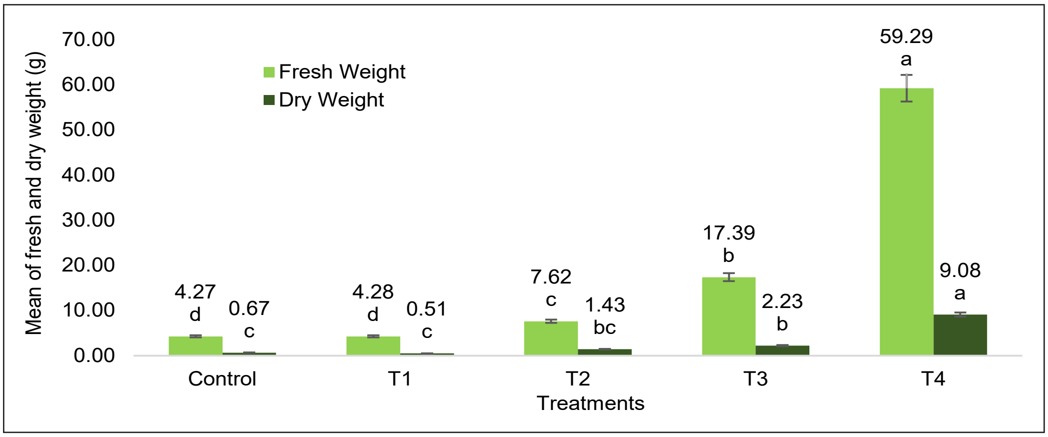

Figure 5. Effect of treatments on fresh and dry weight (g) in okra (*Abelmoschus esculentus*) at the end of 8 weeks of growth

Note. Small letters display mean separation between treatments within a particular type of weight measured (fresh or dry) using Tukey's test at a 5% level. Different letters are significantly different between treatments applied for the particular week.

application of organic manure could be related to the efficient effect of solubilization of the released plant nutrients, resulting in improved soil nutrients and a water-holding capacity (Tiamiyu et al., 2012). The results corroborated the finding of Premsekhar and Rajashree (2009) in Okra (*A. esculentus*), which indicated that increased yield response of crops following organic manure application could be attributed to improved physical and biological properties of the soil, resulting in an adequate supply of nutrients to the plants (Premsekhar & Rajashree, 2009). When nutrients are available in the appropriate quantities, photosynthetic activity will increase, resulting in an increase in light interception, dry matter formation, accumulation, and partitioning (Uka et al., 2013). In addition, the dry matter weight of the plant will rise as a result of greater root development, which will promote water translocation and nutrient uptake to plant parts (Razak et al., 2017).

Effect of Treatments on Soil pH

It can be observed in Figure 6 that during the initial week (week 1) of planting, the soil pH was the same regardless of treatments which were quite acidic (pH 4.19). However, from week 3 to week 8, treatment with organic waste fertilizer started to display a significant increase in pH. However, okra applied with T4 (NPK 12:12:17:2 10 g + chicken manure 25 g) significantly showed the highest soil pH value from week 3 to week 8, which was about pH 5.2, followed by T3 (NPK 12:12:17:2 10 g + biochar 25 g) which was pH 5.03, T2 (NPK 12:12:17:2 10 g + vermicompost 25 g) recorded at pH 5.02, T1 (NPK 12:12:17:2 20 g) resulted at pH 4.79 and the lowest mean of soil pH value was T0 (No fertilizer) which was at pH 4.47. Such increase in pH after treatment applications were possibly attributed to ion exchange reactions which occur when terminal hydroxide (OH^{-}) of aluminum

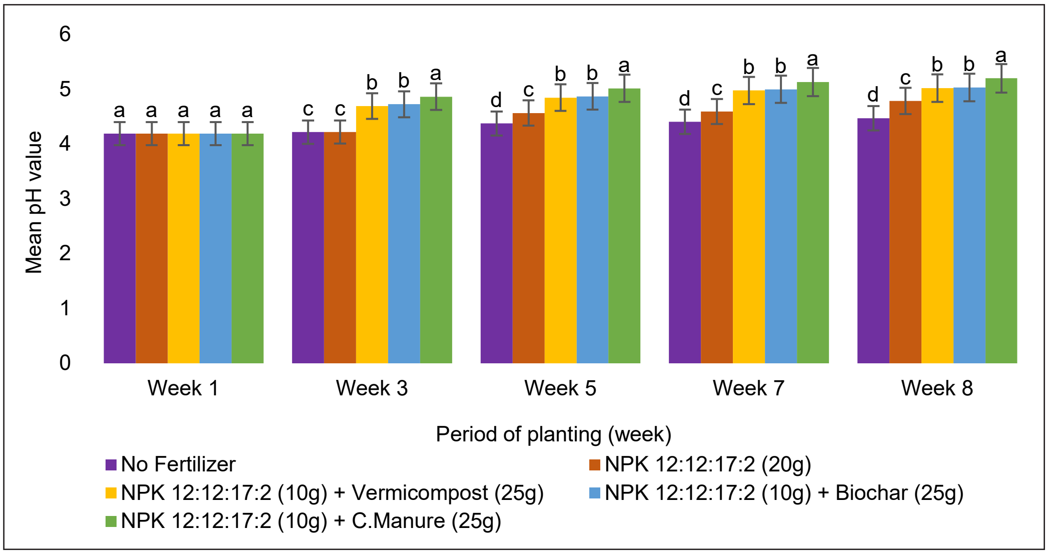

Figure 6. Effect of treatments on soil pH planted with okra (*Abelmoschus esculentus*) during week 1 (before transplanting) to week 8 of growth

Note. Small letters display mean separation between treatments for a particular week using Tukey's test at a 5% level. Different letters are significantly different between treatments applied for the particular week.

(Al) or ferrous ion (Fe^{2+}) hydroxyl oxides are replaced by organic anions, which are decomposition products of the manure such as malate, citrate, and tartrate (Bessho & Bell, 1992; Hue & Amiens, 1989; Pocknee & Summer, 1997; Van et al., 1996).

Another explanation was the presence of basic cations in poultry manure, such as calcium (Ca) and magnesium (Mg). Nätscher and Schwertmann (1991) reported that such basic cations are released upon microbial decarboxylation during decomposition. Organic manures promote soil fertility by stimulating microbial activity and biomass in the soil, increasing the physical and biological properties of the soil (Akande et al., 2010). The addition of organic materials was said to increase soil pH, and this result agreed with the findings by Akande et al. (2004) and Duruigbo et al. (2007) that the application of organic materials will ameliorate crop production in slightly acidic tropical soil. Hence, the application of organic fertilizer can act in 2 ways, providing nutrients for plants and increasing soil pH as it acts as a liming material.

Overall, this experiment was able to successfully substantiate that reducing the dependency on the amount of NPK fertilizer to only half of the amount applied and by adding organic waste fertilizer not only able to produce yield comparable to having applied the full amount of NPK fertilizer that is required but also produced a yield that is significantly much higher than applying NPK fertilizer alone. Hence, since the okra treated with the combination of NPK fertilizer and chicken manure showed the highest growth and development compared to other organic waste fertilizers; therefore, such practice in the production of vegetables like okra should be encouraged.

Recommendations

It is highly recommended for farmers to apply chemical fertilizers according to the standard timing of application (week 2 and week 6 after transplanting) but with half of the recommended dosage to reduce the dependency on chemical fertilizers while also thoroughly mixing chicken manure with the planting medium at a rate of 25 g/10 kg of soil. Not only will this reduce the amount of wastage from poultry farming, but it will also reduce the cost of buying chemical fertilizer while recycling and performing agricultural activities in an eco-friendly approach.

CONCLUSION

The application of organic waste fertilizers, such as chicken manure, biochar, and vermicompost, had a significant effect on the growth and yield of okra (*Abelmoschus esculentus*), particularly plant height, the number of leaves and fruits, chlorophyll content, fresh and dry weight, and soil pH compared to the application of NPK fertilizer alone. Okra treated with the combination of 10 g of NPK fertilizer (12:12:17:2) with 25 g of chicken manure showed the highest growth and development compared to other organic waste fertilizers.

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