Effects of Biochar and Compost Applications on Soil Properties and Growth Performance of *Amaranthus* sp. Grown at Urban Community Garden

Jemima Japakumar\(^1\), Rosazlin Abdullah\(^{1,2}\) and Noor Sharina Mohd Rosli\(^1\)

\(^{1}\) Institute of Biological Sciences, Faculty of Science, Universiti Malaya, 50603 Kuala Lumpur, Malaysia
\(^{2}\) Centre for Research in Biotechnology for Agriculture (CEBAR), Universiti Malaya, 50603 Kuala Lumpur, Malaysia

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\(^{*}\) Corresponding author:
E-mail: rosazlin@um.edu.my

**ABSTRACT**

Soil quality and fertility deterioration due to the development in urban areas can cause a significant limitation on the yield and sustainability of crops. A field study was done to investigate the effects of biochar and compost application on soil properties and growth performance of *Amaranthus* sp. grown at urban community garden in Taman Seri Sentosa, Lembah Pantai, Kuala Lumpur. The study was organized using the randomized complete block design (RCBD) with five treatments and four replicates. The treatments are T1 (soil only as a control), T2 (soil+fertilizer), T3 (soil+fertilizer+biochar), T4 (soil+fertilizer+compost) and T5 (soil+fertilizer+biochar+compost). In this study, the treatment which consists of both biochar and compost gave the significant increases and highest reading of plant height (50.40 cm), number of leaves (18), plant leaves width (91.61 mm), chlorophyll content (34.3 \(\mu\)mol/m\(^2\)), plant fresh weight (1.51 kg), dry weight (11.42 g), soil organic matter (10.25%) and soil organic carbon content (5.95%) compared to other treatments. As a conclusion, the combination biochar and compost give the best effects in enhancing the soil properties and growth performance of *Amaranthus* sp. grown at urban community garden.

**INTRODUCTION**

Rapid urbanization that has been occurring worldwide has greatly decreased the amount of sustainable agricultural land and caused issues at the field of food security (Guitart, Pickering, & Byrne, 2012). Food security had been explained as a condition that occurs when "all people, at all times have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" during the 1996 Food and Agriculture Organization (FAO) Rome World Food Summit (Pérez-Escamilla, 2017). A community garden is an area of land that is used for planting crops which is done cooperatively by a group of people that lives in the same urban region and this garden gives advantage to the people that lives in the same urban areas as it offers them a site to cultivate fresh vegetables and fruits, which will assist in developing a long-lasting food system (Tharrey, Perignon, Scheromm, Mejean, & Darmon, 2019). Urban gardening also helps to increase and maintain the food security in urban areas by increasing global food production and exploiting new places and areas for planting (Eigenbrod & Gruda, 2015). Most of our world’s poorest citizens resides in urban areas of developing countries, thus allowing urban poor to produce their own food would enable them to save a great amount of money (Eigenbrod & Gruda, 2015).

The depletion of soil fertility and the decline in the productivity of agricultural crop due to the reducing quantity of organic matter and the imbalances of nutrients inside the soil are the main problems of tropical agricultural soils nowadays (Agegnehu, Srivastava, & Bird, 2017). Urban soils...
are usually linked with degraded and contaminated soils, low in soil organic carbon (SOC) and biological activity, compared to the soils in non-urban areas (Tresch et al., 2018). The degradation of soil causes food insecurity directly and indirectly in which the direct effects are the decline in crop yields and also in their nutritional value. The indirect effects posed by soil degradation are those that related to pollution of soil, air, and water that bring serious problems on human health (Lal, 2009). Therefore, organic amendments can be added in for soil reclamation processes (Pham et al., 2021). These amendments may play a part in the improvement of biological, chemical and physical properties of the soils (Larney & Angers, 2012).

Biochar is described as an organic matter that is rich in carbon. The substance was an organic modification and the aftermath from the pyrolysis process of biomass carried out in high temperature and minimum amount of oxygen (Billa, Angwafo, & Ngome, 2019). Biochar usage has been reported to amplify the quality and fertility of soil through the increment of the pH of soil, upgrade the capacity in holding the moisture, attract more beneficial microbes and fungi, create improvisation for cation exchange capacity, and lastly, preserve the minerals found in the soil (Adedayemi & Idowu, 2017). Because of the characteristics of biochar which are high in surface area and density, the usage of biochar enables preservation of existing nutrients and water inside the soil of the plants thus reducing the leaching of chemical sourced from agriculture (Krishnakumar et al., 2014). Apart from that, a study suggested that there is an increment in soil pH value through the application of biochar as it was reported that the pH of soil at the tea garden increased from 3.33 to 3.63 with the usage of rice husk biochar (Wang, Yin, & Liu, 2014). Biochar has the potential to improve the electrical conductivity in soils by 124.60%, increasing the cation exchange capacity by 20.00% and decreasing 31.90% of the soil’s acidity (Ding et al., 2016). Favourable results were also reported on the soil active organic carbon components through the application of biochar, which includes the increment of fresh organic carbon input of the crops and crop biomass, enhancement of the soil structure, promotion in the formation of soil aggregate and supplying an optimal habitat for soil microorganisms (Yang et al., 2020).

Compost is comprised of organic materials which are balanced and deteriorated due to the degradation of organic materials aided by controlled, oxygenated conditions (Adugna, 2016). The utilization of compost is eco-friendly and natural thus compost provides a great way to make improvement to the soil fertility and finally contributes to the increase of crop yield (Afriyie & Amoabeng, 2017). Moreover, soil needs organic matter as it is important to sustain the fecundity of the soil and reduce the nutrient losses. Therefore, compost has both nutrients and organic matter that act as a good organic fertilizer for the soil (Adugna, 2016). When compost is incorporated into soil, it will be mineralised and provides a long lasting release of available nutrients to the plants (Ngo & Cavagnaro, 2018). The study by Lee et al. (2019) stated that the usage of composts sourced from food waste escalated the values of pH, total carbon (TC), the electrical conductivity of soil and the exchangeable sodium percentage (ESP) contents in unsaturated soils from highlands and water saturated paddy. According to Mensah & Frimpong (2018), the incorporation of compost and biochar in terms of usage enhanced the soil quality, increased the growth of the plant and provided a positive synergistic result on the nutrient contents of the soil under field conditions. These synergistic process included the reduction of chemical fertilizer application, improvement of the performance of nutrient, soil structure stabilization and increment of the water holding capacity.

*Amaranthus* or amaranth is known as a diverse genus of short-term perennial plants. The amaranth plant had been categorized in the genus of *Amaranthus*, order Caryophyllales, family Amaranthaceae, and sub-family Amaranthoideae. Amaranth plant consists of branched annual herbs which has estimation of 70 different species where 17 of the species are suitable for eating and cooking (Peter & Gandhi, 2017). Despite being missing in the agriculture field for centuries after establishing its superiority, it has remerged with a strong start exhibiting good potential for food and nutritional security globally and also has the capability to be utilised as a leafy green vegetable or grain thus proving that its nutritional value is high in a wide range of contexts (Hoidal, Díaz Gallardo, Jacobsen, & Alandia, 2019). The amaranth leaves comprise of 17.50-38.30% of dry matter which serve as crude protein and average of 5.00% lysine so it has a great potential to be used as a supplement that provides protein to human body (Srivastava,
2011). The *Amaranthus* sp. like a number of other vegetables requires soil that contains high organic content that supplies plant with the nutrient required for optimum performance. Therefore, this research was done to study the effects of biochar and compost application on soil properties and growth performance of *Amaranthus* sp. grown at urban community garden.

**MATERIALS AND METHODS**

**Research Area and Experimental Design**

This study was conducted at the urban community garden in Taman Sri Sentosa, Lembah Pantai, Kuala Lumpur from December 2019 until February 2020. The pH of the soil at the urban community garden is 6.63. The field study was constructed using randomized complete block design (RCBD) with 5 treatments and 4 replicates (Table 1). A total of 20 seedbed plots were built inside the pallet collar box with 1.00 x 0.50 m area. The type of seedbed used was raised bed where the soil was raised three quarter of the height of pallet collar box. The soil amendments were mixed thoroughly into each raised beds 15 days before sowing the seeds.

Biochar used in this research is rice husk biochar from Tanjung Karang, Selangor. The pH value is 9.20, total organic carbon is 43.41% and total nitrogen is 0.50%. The compost used is food waste compost from University of Malaya Zero Waste Campaign. The compost has pH of 6.35 with total organic carbon of 31.00% and total nitrogen (N) of 1.90%. The fertilizer used is NPK green (15:15:15). The *Amaranthus* sp. seeds was sowed directly into the seedbed on 6/1/2020 and the plant was harvested after 4 weeks (28 days) which was on 3/2/2020. The *Amaranthus* sp. was watered daily in the morning before 10.00 am and in the evening after 5.00 pm. The fertilizer was added weekly for each plot starting week 2 until week 4 of the growth of *Amaranthus* sp.

**Growth Performance of *Amaranthus* sp.**

The growth performance of *Amaranthus* sp. were measured weekly. The parameters of growth performance were the plant height, number of leaves, leaf width and chlorophyll content using five plants with homogenized height in each plot. A meter ruler was utilised to measure the height of plant starting from the bottom of the shoot which is located at the surface of the soil until the end of the tallest leaf in the plant's foliage (Mensah & Frimpong, 2018). The number of leaves of the *Amaranthus* sp. plant was counted manually, and the plant leaves width was measured using a vernier calliper. The amount of chlorophyll present in the leaf of the plant was assessed by utilizing a chlorophyll meter (SPAD-502 Plus, Minolta, Japan). Fresh weight of all the plants from each plot was measured using weighing balance after harvesting meanwhile the dry weight was measured by choosing six plants with homogenized height from the fresh weights. The chosen plants were wrapped in an aluminium foil and then it was dried in the oven with the temperature of 65°C until constant weight was achieved. This is to make sure the dry weight of the *Amaranthus* sp. plant can be obtained.

**Soil Properties Analysis**

The soil sampling was done after the plant was harvested using soil auger at the depth of 0.00-15.00 cm. The soil samples from the site were homogenized, air-dried, ground and passed through a 2.00 mm sieve size to be used for the soil analysis. Soil pH was determined in 1:2.5 soil to distilled water ratio (w/v) using Ohaus ST300 Portable pH meter and soil electrical conductivity (EC) was assessed in 1:5 soil to distilled water ratio (w/v) using HI 2315 Conductivity meter (Trupiano et al., 2017). The organic matter (OM) that is present inside of the soil was determined by using loss of ignition method (Leelamanie, Liyanage, & Rajaratnna, 2015). The conversion factor 1.724 was used to predict the soil organic carbon according to the supposition stating that organic matter contains 58.00% of organic carbon content (Pribyl, 2010).

**Statistical Analysis**

The software that was utilized to carry out the statistical analysis for this study is IBM SPSS Statistics 26. The analysis of the significant differences of all the treatments was done through one-way ANOVA. The post-hoc test that had been used for this study is Tukey’s test. The correlation between all the parameters studied (plant height, number of leaves, leaves width, chlorophyll content, fresh weight, dry weight, soil pH, soil electrical conductivity, soil organic matter and soil organic carbon) was measured using Pearson’s correlation coefficient. Microsoft Excel 2016 software was used for the computation of graphs and figures.
RESULTS AND DISCUSSION

Effect of Biochar and Compost on Growth Performance of *Amaranthus sp.*

Fig. 1A shows that the biochar and compost applied to the soil has positively affected the plant height of *Amaranthus* sp. The plant height increases from week 1 until week 4 in all treatments. Not only that, a significantly higher (p<0.05) plant height was recorded on the plants treated by soil amendment compared to control in week 4. The highest plant height was found in T5 (FBC) at 50.40 cm and the lowest was observed in T1 (C) with the value of 12.20 cm. The applications of biochar and compost will increase the content of carbon (C) and enhance the aggregation and macro porosity of soil and decrease the resistance of penetration, thus resulted in the improvement of the plant growth (Rosenani, Rovica, Cheah, & Lim, 2016).

Next, the usage of biochar and compost has also positively affected the number of leaves of the *Amaranthus* sp. (Fig. 1B). The least number of leaves was observed in the treatment T1 (C) with the value of 9 while the highest number of leaves was obtained at T5 (FBC) and T4 (FC) with the value of 18. The plants treated with only biochar and compost treatment showed not significant number of leaves compared to those treated with fertilizer. However, combination of organic amendment of biochar and compost significantly increased the number of leaves compared to the control and fertilizer treatments. This shows that the incorporation of biochar and compost can also help in increasing the number of leaves of *Amaranthus* sp. plant.

The leaf width also increases significantly in the treatment of biochar, compost and their combination respectively. The highest leaf width was obtained by T5 (FBC) at of 91.61 mm and the lowest is T1 (C) at 28.13 mm. This shows that the addition of biochar and compost plays a part in boosting the plant leaves width.

On chlorophyll content, T1 (C) shows a significant difference among the other treatments. The plant with single application of fertilizer shows a significant different chlorophyll content between T5 (FBC) but it has negligible differences with T3 (FB) and T4 (FC). The highest chlorophyll content is obtained at T5 (FBC) with the value of 34.3 µmol/m² and the lowest is T1 (C) with the value of 21.8 µmol/m². The significance of chlorophyll content is an indicator to determine the photosynthetic activity of the plant leaves. The chlorophyll is connected with the nitrogen content found in green plants and it also plays a crucial role in measuring the response of plants towards the fertilizer application and the level of soil nutrients (Agegnehu, Bass, Nelson, & Bird, 2016). A previous study conducted by Agegnehu, Bass, Nelson, & Bird (2016) had shown that the application of fertilizer combined with biochar and compost significantly increased the chlorophyll content of plant leaf compared to the application of fertilizer alone.

For the overall plant growth performance, the treatment that consists of biochar and compost gives the most excellent result among the other treatments. These treatment gave the highest plant height, number of leaves, leaf width and chlorophyll content. This shows that both biochar and compost either by stand-alone or in combination have ability to improve the growth performance of the plant. According to Liu et al. (2021), the combination of the two amendments is more effective in increasing the plants development than applying each amendment separately. This is proved by the study conducted by Schulz, Dunst, & Glaser (2013) where biochar does not only help in accelerating plant growth, but it is also capable to increase the effectiveness of fertilizer particularly when incorporated with organic fertilizer like compost.

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### Table 1. Treatment description of fertilizer, biochar and compost

| Treatment | Description | Fertilizer (kg/seedbed) | Biochar (kg/seedbed) | Compost (kg/seedbed) |
|-----------|-------------|-------------------------|----------------------|----------------------|
| T1 (C)    | Soil only (without soil amendments) | - | - | - |
| T2 (F)    | Soil with fertilizer | 0.030 | - | - |
| T3 (FB)   | Soil with fertilizer and biochar | 0.030 | 1.000 | - |
| T4 (FC)   | Soil with fertilizer and compost | 0.030 | - | 1.000 |
| T5 (FBC)  | Soil with fertilizer, 50% biochar and 50% compost | 0.030 | 0.500 | 0.500 |
Effect of Biochar and Compost on Fresh weight and Dry weight of *Amaranthus* sp.

Fig. 2A and Fig. 2B shows the fresh and dry weight of the *Amaranthus* sp. plant after harvest. T1 (C) shows a significant decrease among the other treatments in the fresh weight of *Amaranthus* sp. The treatment that has the highest fresh weight yield is T5 (FBC) at 1.51 kg and the lowest is recorded on T1 (C) which has only 0.15 kg. The highest fresh weight yield is influenced by the combination of both biochar and compost because best results are obtained for the parameters of plant height, number of leaves, width of plant leaves and chlorophyll content. These findings are related to the study conducted by Senevirath, Sutharsan, Srikrishna, & Paskaran (2019) by which mixture of biochar and compost contributed to the increment in total biomass by 16.52% in comparison to the control treatment on soybean plants and the reason behind the increase of biomass was due to the increase in plant growth parameters. The dry weight of T1 (C) and T2 (F) showed a significant difference with T5 (FBC). The best dry weight yield was also obtained by T5 (FBC) at 11.42 g and the lowest is T1 (C) at 0.90 g. Fig. 3 and Fig. 4 show the usage of biochar and compost only and also in combination played a crucial role in increasing the fresh and dry weight of plant compared to control condition and single fertilizer treatments. According to Liu et al. (2017), the application of biochar as a soil amendment is an
effective way to decrease the nutrient leaching and increase the nutrient bioavailability in the soil. Based on previous research, the incorporation of biochar enables the reduction of inorganic nitrogen (N) leaching and promotes the increase in nitrogen (N) retention within the soil (Liu et al., 2017). Besides, the compost usage can enhance the growth parameters of the plant since compost can supply different types of nutrient such as phosphorus, humic acid, potassium, nitrogen and organic carbon to the plant (Namasivayam & Bharani, 2012).

Fig. 2. Effect of biochar and compost on (A) fresh weight and (B) dry weight of Amaranthus sp. Each data item in the vertical bar indicates the mean of the replicates. The error bar indicates the standard deviation. T1 (C) = control, T2 (F) = fertilizer only, T3 (FB) = fertilizer and biochar, T4 (FC) = fertilizer and compost and T5 (FBC) = fertilizer and combination biochar and compost. Mean followed by the same letter are not significantly different (p < 0.05)
Fig. 3. Effect of soil amendment on growth performance of *Amaranthus* sp. photo was taken 27 days after sowing the seeds
Effect of Biochar and Compost on Soil Properties

Results in Fig. 5A shows that T1 (C) and T2 (F) shown a significant difference between the soil amended treatments. T3 (FB) has the highest pH value at 7.12. The soil pH has turned to alkaline due to the addition of biochar in that treatment. The biochar used in this research is rice-husk biochar which has the pH of 9.20. Based on research by Shah, Sara, & Shah (2017), the biochar usage has proved to increase the soil pH and the soil electrical conductivity. The lowest pH was obtained by T2 (F) at 4.41. The addition of fertilizer without biochar and compost has decreased the soil pH turning it into more acidic because the initial soil pH of the urban community garden before planting is 6.63. The decrement in soil pH with the addition of fertilizer could be due to the leaching of the positively charged ions like magnesium, calcium, and potassium from the soil because of rainfall (Ozlu & Kumar, 2018).

In another study conducted by Mensah & Frimpong (2018) showed that the usage of biochar and compost either by stand alone or in combination had accelerated the pH of soil significantly.

Fig. 5B shows that there is a significant difference of electrical conductivity (EC) at T1 (C), T2 (F) and T3 (FB). T4 (FC) has the highest electrical conductivity at 0.45 mS followed by T5 (FBC) at 0.43 mS. The similarity between T4 (FC) and T5 (FBC) is the addition of compost in both these treatments. This shows that compost is an organic amendment that increases the soil electrical conductivity. Another research carried out by Angelova, Akova, Artinova, & Ivanov (2013), shows that there is an increasing in the electrical conductivity when compost is applied to the soil. The mixture of compost into the soil will increase the salt content and also the electrical conductivity of soil particularly due to the high salinity of composts (Angelova, Akova, Artinova, & Ivanov, 2013).

Next, based on Fig. 5C there is a significant difference between T1 (C) and T5 (FBC) in the percentage of soil organic matter. T5 (FBC) has the highest percentage of soil organic matter at 10.25% while T1(C) has the lowest at 6.88%. T5 (FBC) has the highest percentage of soil organic matter, which could be attributed to the incorporation of biochar and compost, both of which are organic amendments high in organic matter. Because of its high stability towards degradation in the soil, the biochar application will make a lifelong increase in

Fig. 4. Effect of soil amendment on growth performance of *Amaranthus* sp. photo was taken after harvesting
soil organic matter that will give benefit to all the main functions exhibited by the organic matter that is present in the soil (Sánchez-Monedero et al., 2019).

There is a significant difference between T1 (C) and T5 (FBC) observed from Fig. 5D. T1 (C) has the lowest carbon content at 3.99% while T5 (FBC) has the highest percentage of carbon at 5.95%. These condition was related to the high amount of organic matter content of biochar and compost, thus contributed to increase carbon content in the soil. Compost and biochar are composed of high organic carbon, therefore, these soil amendments are utilised in order to enhance the carbon sequestration in the soils because soils in urban area are commonly lacking in available nutrients, carbon and biological activity (Ghosh, Ow, & Wilson, 2015).

Remarks: Each data item in the vertical bar indicates the mean of the replicates. The error bar indicates the standard deviation. T1 (C) = control, T2 (F) = fertilizer only, T3 (FB) = fertilizer and biochar, T4 (FC) = fertilizer and compost and T5 (FBC) = fertilizer and combination biochar and compost. Mean followed by the same letter are not significantly different (p < 0.05)

**Fig. 5.** Effect of biochar and compost on (A) soil pH, (B) soil electrical conductivity, (C) soil organic matter, and (D) soil organic carbon
Table 2. Correlation analysis between growth performance and soil properties of *Amaranthus* sp. by Pearson method

| Parameter          | Plant Height | Number of Leaves | Leaf Width | Chlorophyll Content | Fresh Weight | Dry Weight | Soil pH | Soil EC | Soil OM | Soil OC |
|--------------------|--------------|------------------|------------|--------------------|--------------|------------|--------|--------|--------|--------|
| Plant Height       | -            |                  |            |                    |              |            |        |        |        |        |
| Number of Leaves   | 0.945**      | -                |            |                    |              |            |        |        |        |        |
| Leaf Width         | 0.980**      | 0.956**          | -          |                    |              |            |        |        |        |        |
| Chlorophyll Content| 0.920**      | 0.897**          | 0.937**    | -                  |              |            |        |        |        |        |
| Fresh Weight       | 0.974**      | 0.927**          | 0.954**    | 0.869**            |              |            |        |        |        |        |
| Dry Weight         | 0.951**      | 0.929**          | 0.965**    | 0.902**            | 0.958**      | -          |        |        |        |        |
| Soil pH            | 0.292        | 0.404            | 0.384      | 0.322              | 0.396        | 0.447*     | -      |        |        |        |
| Soil EC            | 0.762**      | 0.808**          | 0.846**    | 0.805**            | 0.772**      | 0.843**    | 0.591** | -      |        |        |
| Soil OM            | 0.527**      | 0.690**          | 0.607**    | 0.610**            | 0.519*       | 0.558*     | 0.521*  | 0.630** | -      |        |
| Soil OC            | 0.527**      | 0.690**          | 0.607**    | 0.610**            | 0.519*       | 0.558*     | 0.521*  | 0.630** | 1.000**| -      |

Remarks: **Correlation is significant (0.01 level); *Correlation is significant (0.05 level); Soil EC = Soil Electrical Conductivity, Soil OM = Soil Organic Matter and Soil OC = Soil Organic Carbon

Correlation between Soil Properties and Growth Performance of *Amaranthus* sp.

Table 2 shows the correlation between soil properties and growth performance. Soil pH has a moderate positive correlation with number of leaves, plant leaf width, chlorophyll content, fresh weight and dry weight of *Amaranthus* sp. but then it has a weak correlation with plant height, $r = 0.292$. Soil electrical conductivity is strongly correlated with plant height ($r = 0.762$), number of leaves ($r = 0.808$), plant leaf width ($r = 0.846$), chlorophyll content ($r = 0.805$, fresh weight ($r = 0.772$), dry weight ($r = 0.843$) and soil pH ($r = 0.591$) of *Amaranthus* sp. This shows that soil electrical conductivity strongly influences plant height, number of leaves, leaf width, chlorophyll content, fresh weight, dry weight and soil pH of *Amaranthus* sp. Soil organic matter and soil organic carbon show strong positive correlation with plant height ($r = 0.527$), number of leaves ($r = 0.690$), plant leaf width ($r = 0.607$), chlorophyll content ($r = 0.610$), fresh weight ($r = 0.519$), dry weight ($r = 0.558$), soil pH ($r = 0.521$) and soil electrical conductivity ($r = 0.630$). This shows that soil organic matter and soil organic carbon content also influences the plant height, number of leaves, leaf width, chlorophyll content, fresh weight, dry weight, soil pH and soil electrical conductivity of *Amaranthus* sp. Soil organic matter (SOM) is crucial in indicating the soil productivity and it also aids in increasing water holding capacity, structure, texture and nutrients availability in soil to enable continuous sustainability of the plants grown (Fageria, 2012).

CONCLUSION

As a conclusion, the usage of biochar and compost helps in enhancing the soil properties and also the growth performance of *Amaranthus* plant. The results data from this research has shown that both of this soil amendments had given a positive impact towards the soil properties and on the growth performance of *Amaranthus* sp. plant. The combination of biochar and compost gave the best results in improving plant height, number of leaves, plant leaves width, chlorophyll content, plant fresh and dry weight, soil organic matter and soil organic carbon content. It also has increased soil pH and electrical conductivity. Thus, the combination of biochar and compost in a treatment gives the best results in improving the soil properties and growth performance of *Amaranthus* sp. grown in an urban community garden.

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