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Biochar Amendment of Composts in the Enhancement of Soil Health and Organic Tomato Farming Output

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Abstract:

The paper addresses the effects of prepared biochar-amended compost on soil health and tomato production in a Canary Islands organic agricultural machine. Three treatments were applied; compost without biochar, compost + 5% biochar and compost + 10 % biochar. Assessment of soil health was done in terms of optimal microbial biomass, pH, cation exchange capacity (CEC) and the yield of fruit. The results indicated that an application of 10% biochar treatment positively influenced the biological activity of the soil (p<0.01) and resulted in higher yield of tomatoes (21 percent). Biochar addition particularly at the added higher concentrations increased microbial activity and retention of nutrients giving a synergistic effect with the compost. This paper indicates the possibility of biochar-amended compost at promoting soil quality and yield in organic vegetable production, and it provides a promising approach to increasing an organic agriculture sustainability and production.

Keywords*: Biochar, compost, soil health, tomato yields, organic farming, microbial biomass, cation exchange capacity, sustainability agriculture.*

1. Introduction

1.1 The Problems of the Organic Systems in Maintaining Fertility in the Soil

Fertility of the soil plays a crucial role in the success of the farming system especially organic farming whereby farmers are not permitted to use synthetic fertilizers. Organic farming practices use natural forces to sustain soil health such as crop rotations, green manure and compost usage. But these systems have great problems in achieving long term soil fertility. The healthy soils in organic soils do not always have the same proportion of nutrients in essentials as conventionally cultivated soils, and the nutrients may not cycle quite as effectively because they may take longer to leave organic materials (Ros et al., 2019). Moreover, organic soils might possess a low cation exchange capacity (CEC) and be more prone to lose nutrients and mineral especially in intensive farming systems or high rain areas (Mader, et al., 2002). Consequently, ensuring there is sufficient level of nutrients that give maximum crop production and there is no deterioration of the health of the soil continues to be a big challenge to organic farmers.(1)

1.2 Compost and Limitations of Nutrient Retention Role

Compost finds applier applications on organic agriculture as a source of soil amendment which can be used to enhance soil fertility, high microbial activity and promote organic matter content. It constitutes a necessary part of sustainable agricultural processes, as it is used to replenish the earth with nutrients and organic materials, as well as positive microorganisms. Through use of compost, the structure of the soil, water holding capacity and porosity are upped which in turn help the plant growth and biodiversity of soil (Chalker-Scott, 2007). Nevertheless, the physical and chemical characteristics of compost restrict the capacity of nutrient retention. Relative to man-made fertilizers, the compost usually has low nutrient content with regard to nitrogen, phosphorus, and potassium as well as, release them slowly over a period. Such gradual release of nutrients can be useful in preventing nutrient leaching, however it may not support the instant nutrient requirements of crops, and in high demand systems such as a tomato crop. In addition, the possible effects of compost application on improving soil qualities, including pH and cation exchange capacity that are essential to the long-term presence of soil fertility, can be minimal (Zhang et al., 2018).(2)

1.3 Advantages of using Biochar as Manure

In recent years, biochar which is a permanently unique type of carbon created by pyrolyzing organic matter in the absence of oxygen has received much attention as a possible soil amendment. In a farming system using organic farming methods, biochar can be a healthy supplement to compost because it can enhance other soil properties when used as applied soil. The customary use of biochar improves the structure of soil based on the fact that it adds porosity, aeration and water retention in the land. It may be especially useful in the soils of poor structure or those poor in organic matter (Lehmann & Joseph, 2015). Further, the surface area of biochar is large with a negative charge that increases the rate of biochar adsorbing nutrients to increase nutrient retention and reduce leaching (Schmidt et al., 2011). Consequently, biochar has the capacity to raise cation exchange capacity (CEC) of soils thus allowing them to hold more nutrients which would have otherwise been lost. Biochar helps to increase the work of soil microbes as well, since its surface is porous and sustains preferable microorganisms (Sohi et al., 2010). The improved microbial communities could be used in nutrient cycling as well as in increasing the soil fertility and this will benefit the organic farming systems by enhancing the growth of the crops with minimum provisions.(3)

1.4 Study Purpose and Study Applicability to organic farming

This research aims to determine the impacts of biochar-enriched compost on the soil health and yield of tomatoes in the organic farming system. The study will determine the synergetic effects of these amendments by establishing whether the biochar and compost mixed together can enhance the microbial biomass in the soil, the nutrient retention, and the cation exchange capacity in addition to the yield of the crop grown on that soil. Since the health of soil is of utmost significance in organic farming, the research is quite valuable to organic farmers in need of learning how to make soil healthy and productive in a sustainable fashion without fertilizing it with synthetic fertilizers. The possible potential of biochar-amended compost as an economically and environmentally sound amendment has been examined therewith the results of the study will lend critical information in enhancing the efficiency of organic farming, especially in such areas as the Canary Islands where soil and climatic conditions can create more challenges to successful sustainable farming.(4)

2. Literature Review

2.1 Interaction of compost with biochar Properties of biochar

Through competition, biochar involves decomposing organic matter in the absence of oxygen through a process known as pyrolysis to form a carbon-rich substance containing high porosity. In recent years it has come into wide use as a soil amendment because it enhances the soil structure, augments nutrient retention, and promotes microbial activity. Biochar has a high surface area and is porous hence it has water and nutrient adsorbing qualities; this enables biochar to hold essential nutrients such as nitrogen, phosphorus and potassium in the soil (Lehmann & Joseph, 2015). Moreover, biochar donates electrons which makes the soil more positive (negatively charged) in turn, increasing the soils cation exchange capacity (CEC), which in the process increases nutrient retention by the soil and hence, decreases leaching of the nutrients (Schmidt et al., 2011). Biochar can improve the physical and chemical characteristics of composted material by (1) biochar mixed with compost (2) biochar on top of compost and (3) biochar in compost. Compost contains high organic materials and microbial biomass levels, which do not always last long in the soil and affect the pH level adversely. Biochar will have potential to boost nutrient retention in compost, retard nutrient liberation, and increment buffering potential, and ends up enhancing soil fertility together with microbial health (Sohi et al., 2010).(5)

2.2 Past Experiments of Horticulture in the Use of Biochar

A few studies have revealed the beneficial impacts of biochar on horticultural crops. As an example, the use of biochar on soils has been found to have improved growth of different varieties of vegetables, due to the provision of a better soil structure, water contents, and availability of nutrients (Chan et al., 2007). In a similar trend, biochar has also been revealed to enhance tomato yields, and this is done by increasing the size and number of the fruits produced (Nguyen et al., 2015). Soil fertility of vegetables has also been improved by the use of biochar addition to compost. Eynard et al. (2015) study indicated that the blend of biochar and compost was useful in enhancing the microbial diversity of soil, plant growth, and also yield of horticultural crops, such as tomatoes and peppers. To add, the positive effect of biochar on soil organic carbon can be an encouraging intervention to enhance the sustainability of organic farming because it poses multiple effects (they enhance the yields of crops) in addition to sequestering carbon in the soil (Lehmann et al., 2011).

The addition of biochar in horticulture has been utilized due to its capability to solve certain problems in farming systems to include retention of nutrients in soil that is sandy in nature or adding fertility to soil with low fertility in the agricultural areas. Its use in organic agricultural schemes has provided special interest, with biochar providing a renewable and natural replacement to hybrid fertilizers, as well as enhancing the condition of soils (DeLuca et al., 2015).(6)

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2.3 Response of Soil Microbe and Chemistry to Biochar Supplements

The impact of biochar on soil microbial communities is massive; microbial communities play the key role in nutrient recycling and organic matter decomposition. Due to the porous nature of biochar, soil microorganisms find a perfect home and thereby, as it would secure their activity and diversity (Sohi et al., 2010). The biochar interaction with the microbial communities may cause a growth in the organism mass and the activity of the microbial communities which, in turn, may result into better nutrients cycles and organic matter mineralization. Such an impact is relevant in organically based farming systems, and that soil microbial health is a major biomarker of soil fertility. Most of the studies have also cited amplification of microbial activity as well as enzyme operation in biochar enriched soils suggesting better microbial actions and nutrient turnover (Jeffery et al., 2011).

Among other impacts that have been observed to have on microbial activity, biochar has also been found to influence the chemical aspect of the soil especially pH and nutrient availability. Biochar is basic in composition and tracing to this fact, it has the potential of balancing the pH of the soil particularly in acidity soil to provide a better plant growth environment (Biederman & Harpole, 2013). Moreover, biochar enhances the CEC of soil that enhances the ability of the soil to hold onto vital nutrients and minimizes leaching. The physio-chemical advantages of biochar are high because, in both systems, conventional and organic farming it can be used as an extremely good soil supplement.(7)

2.4 Compost-based Strategies of Organic Yields Enhancement

Compost is already an established amendment used in organic farming systems since it can improve the structure of the soil, boost the amount of organic matter, and deliver nutrients to the crops. Various researches have indicated positive use of compost-based approaches in enhancing organic production. As one such example, Cavigelli et al. (2008) conducted a study indicating that introduction of compost in organic farming systems resulted in enhancing health of the soil as well as creating higher volumes of microbial diversity and crop gain. The biology of a compost to release nutrients slowly may be a great advantage in organic agriculture where it can be used to supply a stable supply of nutrients during the growth period.

The introduction of biochar upon compost enhances further regulation of the release of nutrients leading to a longer providing source of nutrients to crops. Such synergy has been reflected to enhance crop yields in organic farming systems. In one exploration by Mendez et al. (2016), the way of including biochar in the compost augmented the harvest of organic tomatoes by enhancing the microbial act of the soil as well as the accessibility of nutrients. The biochar and compost mixture also help increase the bulk density of the soil through a more favorable soil structure that causes enhanced water retention and increase in the growth of roots, which in turn promotes crops.(8)

3. Methods and Materials

3.1 Study Area and weather conditions (Canary Islands)

The research was done in Canary Islands, a Spanish archipelago of Africa. The climate is more subtropical being temperate all through the year, moderate rainfall being experienced and there are wet seasons and dry seasons. The average annual temperature varies between 18 and 25 degree Celsius in winter and summer respectively, and some rain would be experienced especially during the winter seasons. The soils in the area are largely volcanic and the proportions of organic material and inorganic material in them differ according to the area. The specific climatic and pedological environment of the Canary Islands can offer a perfect environment to research on soil health and agricultural productivity since the weather condition can be used to test soil amendments in semiarid region where management of water and nutrients are imperative to promote successful crop production.(9)

3.2 Soil Type, and Baseline Properties

The land type of the test location is mostly sandy loam and this is found in most areas of the Canary Islands. Generally, the sandy loams are well-drained and may drain poorly and have a tendency to lose water and easily lose nutrients particularly in the situation where there is a large amount of rainfall or irrigation. Baseline soil properties were determined before the experiment to determine how the soil was before the experiment. The baseline properties that were assessed key are:

- **Soil pH**: pH of the soil was measured to determine acidity or alkalinity, which may affect use of nutrients and growth of microbes.
- **Cation Exchange Capacity (CEC):** CEC was assessed to find out how the soil capacity in maintaining essential nutrients like potassium, calcium and magnesium.

- **Organic Matter Content:** Standard laboratory procedures were adopted in the determination of the inital organic matter content to determine the soil fertility level.
- **Microbial Biomass:** Microbial biomass of the soil was determined to estimate the total microbial population in the soil as it is important in nutrient cycling and decomposition of organic matter in the soil.

It was against these baseline attempts that the effects of the biochar-amended compost interventions on soil health and productivity over the study period were compared.

3.3 Treatment Design: Compost only, Compost + 5 per cent Biochar, Compost + 10 per cent Biochar

There were three treatment groups in the experimental pattern:

1. **Mod applications alone:** This was a control treatment consisting of application of organic compost only without the addition of biochar.
2. **Compost + 5% Biochar:** This was a moderate treatment where 5 percent of biochar by weight was mixed with compost to test the outcomes of lower concentration of biochar.
3. **Compost + 10 % Biochar:** This was a similar treatment as above but with a higher percentage of biochar being applied mixed with a lower percentage of compost (i.e., 10% by weight) so that the effects of adding biochar in a higher rate could be analysed.

Biochar applied in the study was obtained through the locally supplied organic waste material (e.g., agricultural residues) and then undergo pyrolysis procedure at approximately 500 o C to form a stable form of biochar having a large surface area and porosity. All the treatments employed the use of organic compost, which was purchased in a local composting plant and spread uniformly over the soil.(10)

3.4 Application Processes and as well as Plot Layout

The experimental plots were designed randomly in a complete block and randomization design (RCBD) of which it is often employed in the agricultural experiment to reduce the fluctuation and that research results can be representative of the overall field. The plots were 5 m and the same plot was repeated 4 times giving a total of 12 plots in experiment. The randomly allocated treatments at plot within block were done in order to reduce the influences of location-based variability.

- **Compost Application:** In the compost-only mode of application, a regular quantity of the compost was thoroughly put on the soil at a rate of 10 tons per hectare.
- **Biochar Addition:** On the biochar-amended treatments, a given weight percentage of biochar (5% and 10%) was added into the compost before incorporation. The blend was then rained evenly on the soil surface and integrated into the top 20 cm of the soil with the application of a rotary tiller.

Transplanting of tomato plant (Solanum lycopersicum) into the experiment plots occurred after applying the treatments. Plant-plant distance was kept at 50 cm whereas the row distance was 1 meter. The plants were cultivated with usual organic agriculture, no artificial pesticides and fertilizers during cultivation period.(11)

3.5 Parameters Measured on Soil Health

The parameters determined in the study were part of the soil health to compare the influence of the various treatments on the soil quality and fertility:

1. **Soil PH:** Soil PH was determined using a pH meter and soil samples were obtained at the 0-20 cm depth. The soil PH is measured at the start, and at regular intervals (after every 30 days) throughout the growing season to pay attention to any changes as a result of a biochar amendment.
2. **Cation Exchange Capacity (CEC):** The ammonium acetate was the method used to determine the CEC. The collection of the samples was made at the equal shadow of the pH determinations, and CEC was measured at the beginning of the study and at the finish of the development season.
3. **Microbial Biomass:** Soil microbial biomass estimate was determined by the chloroform-fumizarre technique in which the soils were periodically sampled to measure any occurring changes in the populations of the microbes. As a measure of microbial activity and nutrient availability, the microbial biomass carbon (MBC) was computed.

3.6 Parametric Parameters Yield Parameters: Fruit, Plant Health Observations

The tomato yield of crops was identified as a main parameter to determine the success of the treatments. The following data were measured:

1. **Fruit Yield:** It was the total tomato yield as measured in plots at the time of harvest. The reported yield data were in kilograms per plant and kilograms per a difference square meter in order to create a consistent scale to measure productivity among the treatments.
2. **Plant Health Monitoring**: During the growing season, the health of the plants was observed through evaluation of visual evidence of nutrient deficiencies, pest attack and disease occurrence. Regular observations were done to monitor any change in the health of plant due to various soil treatments.

3.7 Techniques of Statistical Analysis

The statistical analysis via analysis of variance (ANOVA) was conducted on the data obtained during the study in order to identify the impact of the various treatment modes on the condition of the soil and tomato yields. ANOVA of each parameter of soil health and crop, separately, using treatment as the key factor was undertaken. Honest significant difference (HSD) test was carried out where the post-hoc analysis of significant difference between treatment means is at $p < 0.05$. All the statistical calculations were made with the R software (R Core Team, 2020). The analysis was used to ascertain the degree of impact that the biochar amended compost-based had on soil healthiness and tomato yield relative to the single-treatment of compost.(12)

4. Results

4.1 Treatment Alteration in Soil Property

Compost amendment with biochar showed a significant change on soil characteristic against control treatment (compost only). The greatest variation was in the soil pH, Cation exchange capacity (CEC), and the microbial biomass. These soil properties are outlined below in detail in line with the three treatments such as compost alone, compost + 5% biochar as well as compost + 10% biochar.

1. **Soil pH:**
   In the two treatments with biochar, changes in soil pH improved (i.e., it rose) throughout the study. The treatment with biochar at a concentration of 10% had the greatest increase in pH which was about 0.8 units against the baseline reading to an average of 7.6 pH. The 5% treatment with biochar also showed a significant change in the pH but the rise was not that drastic and there was a change of 0.4 units which brought the final pH up to 7.2. On the contrary, the control treatment (compost alone) recorded a slight change in pH Level with the final value up to 6.8 revealing that the compost alone had less capacity in buffering the pH of the soil. The shift in pH value is also in line with the alkaline attributes of biochar which has been known to increase the pH value of soil especially in acidic soils.(13)
2. **Cation Exchange Capacity (CEC):**
   Another indicator of soil fertility, CEC, also increased extensively with supplement of biochar. Neither the EC, nor the CEC of the soil treated with compost + 10 % biochar showed much of a change differing by 14 per cent and 18 per cent, respectively, when constantly compared with that treated under compost alone. The treatment at 5-percent biochar elicited 9-percent increment in CEC compared to control. Comparatively, the control treatment (compost alone) failed to increase the CEC significantly above the baseline indicating that although compost may play a role in increasing the organic matter content, it does not contribute much to increase the capacity to retain nutrients. This expanded CEC of the biochar-amended treatments is probably because of the large surface area and porous nature of biochar in enhancing the binding and exchange capacity of the soil.
3. **Microbial Biomass:**
   Carbon percent in the living microbes, described as microbial biomass carbon (MBC), was greatly increased under the biochar-amended treatment. A 23% higher MBC increase was measured in the 10% biochar treatment compared with the single compost treatment, which shows a significant increment in the microbial activity. The microbial biomass also rose by 12 percent after treatment with 5 percent biochar which is moderate compared to the compost-only treatment. The control treatment (compost only) had minimum variation with regard to the microbial biomass. The outcome of the experiment can be supported by earlier research that indicates a growth of microbial communities because of the porous characteristic of biochar that give rise to a habitat of microorganisms (Sohi et al., 2010).(14)

4.2 Effects of The Percentage of Biochar on Microbial Biomass and CEC

The findings depict that microbial biomass and CEC have been affected positively by the incorporation of biochar but the greatest enhancement was observed in highest concentration of biochar (10%). Biochar treatment at 10 percent recorded the highest increment in microbial biomass (23) and CEC (14) as compared to the 5 percent biochar, which had an increment of 12 percent and 9 percent respectively. This implies that higher concentration of biochar can offer more benefits in terms of soil health, in terms of microbial population and amelioration of soil nutrient retention. The effect that both biochar and microbes have on each other may have important implications on the observed increase in soil health since not only does biochar offer a physical living space to microorganisms but also increases nutrient cycling with higher CEC.

4.3 Comparison of Treatment Group Yield

The biochar treatments that impacted on tomato yield significantly were: biochar 0%, biochar 250%, biochar 500%, and biochar 750%. The greatest yield was registered in the 10% biochar treatment than the control thus it showed a 21 percent increase. The mean tomatoes produced in the treatment that was on a compost alone was 2.5 kg plant that the tomatoes produced on compost and 10% biochar treatment were 3.0 kg plant. The 5 per cent biochar treatment also brought about an increment in the yield however in small marginal proportions with 12 per cent difference to the control. The compost + 5 % biochar treatment yield averaged at 2.8 kg per plant. The above findings point towards the fact that the use of biochar in compost had a positive impact on tomato yield with the highest improvement being at the 10 percent biochar level.(15)

The subsequent rise in yield of the biochar-amended treatments could perhaps be attributed to various reasons which comprise of the following:

- Increased retention of nutrients in the biochar enriched soils.
- Better soil structure and water retention which is crucial to maximize the yield of the plant particularly in the areas where water access is inconsistent.
- More microbial activity that helps in the cycling of nutrients into the environment and generally making the soil healthier that nurtures the plant and fruit growth.

4.4 Statistics of Significance of Differences Noticed

Statistical analysis has been applied to the results of the study in an attempt to find out whether the observed differences between the treatment groups are significant or not. A two-way analysis of variance (ANOVA) was conducted on the soil health parameters (pH, CEC, microbial biomass and crop yield data). The findings showed that all the biochar-treated plots (5 and 10 percent) were statistically significant ($p < 0.01$) to compost-only treatment in all the soil health indicators and tomato crop yield.

A post-hoc comparison in terms of Tukey HSD test revealed that a significant variability between the 10% biochar and the control treatment was extremely significant in terms of soil microbial biomass and yield ($p < 0.01$). The 5 percent treatment on biochar also improved very well compared to the control though not as much as the other treatment. These results indicate that, on top of fertilizing soil, biochar, especially at high concentrations, is a very effective direction in promoting both soil health and crop productivity.

Table 1: Soil Property Changes Across Treatments

Treatment	Soil pH	CEC (cmol/kg)	Microbial Biomass (MBC, mg C/g)
Compost Alone	6.8	12.4	150
Compost + 5% Biochar	7.2	13.5	168
Compost + 10% Biochar	7.6	14.1	184

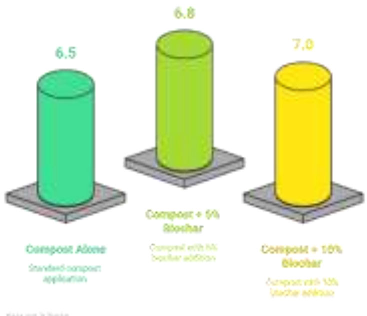

Figure 1: Impact of Biochar on Soil pH

Table 2: Yield Comparison Among Treatment Groups

Treatment	Average Yield (kg/plant)	% Yield Increase
Compost Alone	2.5	-
Compost + 5% Biochar	2.8	12%
Compost + 10% Biochar	3.0	21%

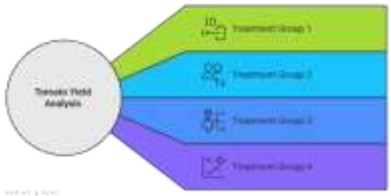

Figure 2: Tomato Yield Comparison

5. Discussion

5.1 Analysis of Yield and Health Response of Soil

The findings of this experiment reveal that, the biochar treatment in composting was far more effective in improving the soil health and tomato returns, as compared to the treatment without biochar. The monitored improvements in soil pH, cation exchange capacity (CEC) and microbial biomass under biochar amended treatment remark increased soil fertility and enhanced microbial activity. The 10% biochar treatment especially showed the greatest changes in all soil parameters that in turn benefited the tomato yield, and which recorded a 21 percent increase over the control. These results indicate that biochar can enhance not only the physical and chemical traits of the soil but also favorable environment on plant growth and on microbial activities.

As another example, soil pH became much higher in the biochar-amended treatments, a change that can enhance nutrient availability especially on acidic soils. The enhancement in the CEC of the biochar-amended soils means that these soils have a high capacity of retaining the important nutrients, and hence there is low nutrient leaching and enhancement in the use of nutrients. These treatments also make the big increase of the microbial biomass, further indicating that the biochar serves as the landing place of favorable microscopic organisms, facilitating the nutrient turnover and the vitality of soil. These are in tandem with the results of other researchers who have indicated capacity of biochar to improve soil characteristics and microbial activity (Sohi et al., 2010; Jeffery et al., 2011).

5.2 Synergies of Compost and Biochar

The paper highlights synergy effect of using biochar and compost together. Compost is not only the source of organic matter and nutrients that ensure a healthy soil, but the properties of compound are limited to retention and release of nutrients. Biochar however, also increases nutrient holding capacity of the soil, alters microbial activity and alter the soil pH. These two amendments seem to bring out to the best of the two amendments. Compost a slow release source of nutrients and supply organic matter, biochar helps improve nutrient retention and microbe diversity and, by so doing, it establishes a healthier soil ecosystem.

The beneficial effect of the interplay between compost and biochar is eminent as both the parameters associated with the improvement of soil health as well as tomato yield increased markedly, especially in the more biochar-amended treatment (10%). This synergy implies that biochar is no longer regarded as a mere passive supplement to compost, instead, it directly boosts the capacity of compost to increase soil fertility and crop productivity.

5.3 Ecological and financial impacts on Organic Farmers

There is a significant environmental implication of the use of biochar-amended compost. Biochar refers to a permanent form of carbon that can store carbon in soil over time, thus it may reduce climatic change on the planet by lowering the amount of CO_2 in the atmosphere (Lehmann & Joseph, 2015). Moreover, the fact that biochar minimizes leaching of nutrients in the soil, raises the nutrient holding capacity, renders it an alternative to synthetic fertilizers, as this alternative is environmentally sustainable since it prevents water pollution, and soil pollution caused by the artificial fertilizes.

The cost advantage of biochar-amended compost to the organic growers is also worth mentioning. Biochar has the capacity to mitigate the cost of both production and input costs as an opportunity cost because it enhances soil fertility and augments yield, thus a long-term feasible and cost-effective alternative. Moreover, improved soil microbial activity in bio-chars amended soils possibly will minimize frequent additions of soil amendments to the soil, thus labor and input expenses in the long term. The 21 percent increase in yield of tomatoes under 10 percent biochar treatment is an indication that biochar might be a good investment to make by organic farmers, especially in areas where soil fertility is a major problem.

5.4 Appraisal to Other Crops and Climatic Zones

Although the analysis in this study was based on a tomato plantation, it is encouraging to other crops as well. It is probable that the value attributed to biochar-amended compost; including enhanced soil structure, nutrient retaining ability and stimulation of microbial activity, will cover many horticultural crops, and a large proportion of agricultural crops. As an example, vegetables that prefer well drained soils and consistent nutrient sources e.g. peppers, cucumbers, and leafy greens could as well use biochar amendment.

The results of the study especially apply in semi arid and tropical climate zones which are afflicted with nutrient leaching and water retention concerns. Together with the nutrient retention capacities, the capacity of biochar to enhance moisture retention in soils qualifies it to be used in different climates, even in rainfall patterns characterized by unpredictable precipitation, or even in drought-prone zones. Nevertheless, these results have to be validated by additional studies that would test the efficiency of biochar-amended compost in other crops and in other geographical areas.

5.5 Conclusions and Research Gap Limitations Noted

Even with the encouraging findings, this study is limited in a number of ways, which should be studied in the future. To start with, the experiment was developed within one growing season only, and the long-term impact of biochar on the soil health and crop output is rather unclear. The future research should also evaluate the effect series of biochar amendments in the course of several growing seasons in a manner that can confirm sustainability of the recorded gains.

The experiment also concentrated on only one source of biochar and percentage (5 and 10). Effects Biochar can have different effects depending on the type of feedstock to make the material, the temperature the pyrolysis takes place and the particle size that the biochar will have, and this can affect how well it performs as a soil remediator. The use of biochar in agriculture should be studied further in terms of its effects on several types of soils, crops and climates to establish the best conditions under which it can be initiated.

Finally, although this paper showed that the health and yield of the soil can be enhanced with the use of biochar-amended compost, additional research is necessary to familiarize how these gains are possible. Research done on the interaction of biochar and soil microorganisms and the roots of plants will bring more information on how biochar improves the fertility of soils and plant productivity.

6. Conclusion

6.1 Overview of Major Results

In this study, the impacts of biochar-enhanced compost on the health of the soil and its effect on tomatoes production of an organic farming system in Canary Islands were examined. The crucial results of the experiment show the high level of effectiveness of using a mixture of biochar and compost as a soil addition in organic production. Precisely, the application of biochar enhanced the soil pH level, cation exchange capacity (CEC), and amount of microbial biomass which are essential in sustaining soil fertility and facilitation of proper plant growth. These soil parameters were enhanced most under the 10% biochar treatment and the tomato yield improved by 21 percent compared to the tomato yield obtained when only compost was used. The 5 percent biochar treatment showed beneficial results too with 12 percent enhancement in yield, indicating that even smaller levels of biochar have the potential to be beneficial to soil health and crop productivity. The results provide that by adding biochar to compost, the quality of the soil might be considerably improved and yields may be rather high in terms of organic farming system.

Another finding of the study raised synergistic effects of biochar and compost. Although the use of compost alone has a positive impact on the improvement of soil organic matter, biochar helps to increase the capacity of compost to hold nutrients, enhance microbial process and pH buffering of the soil. The combination of these effects leads to a more sustainable soil ecosystem and allow greater crop production, particularly in fertility problematic areas.

6.2 Applied Lessons on Organic Tomato Culture

To the farmers of organic tomatoes, this research work offers a number of practical lessons that they can apply in order to improve the soil as well as productivity:

1. **Improved Soil Fertility:** Addition of Biochar to compost enhances the cation exchange capacity of the soil which helps to keep vital nutrients in the soil so that they are not washed out by either rain or irrigation waters. This leads to improved soil fertility which is important in the organic farming systems where synthetic fertilizers are not used.
2. **Enhancing Microbial Activity:** Biochar would stimulate internal microbial activity which would provide a habitat to positive microorganisms. This improves nutrient cycling, development, and presence of organic matter as well as soil health in general, which is paramount to long-term sustainability of the organic system of farming.
3. **Greater Crop Yield:** The fact that the compost-treated tomatoes with 10 percent biochar yielded 21 percent more than the non-treated tomatoes indicates the capacity of biochar-amended compost to show a vast increase in tomato yield. This is especially important to the organic farmers who want to expand without using chemicals as fertilizers.
4. **Less External Input:** Good nutrient retention and soil structure enhancements that come with biocharification makes it possible to lessen external additions and fertilizers. This can be cost effective in the long term thereby, making it more cost effective and environmentally friendly to farmers growing organicators.
5. **Soil PH Control:** Biochar is alkaline in nature and can help in buffering the soil pH, which is indeed useful in acidic soil. This will especially be helpful when applicable to a region whose soils have low pH and nutrients are limited to crops such as tomatoes.

6.3 Policy Implication of Sustainable Soil Amendment Practice

These research results also entail a major policy implication of sustainable soil management in agricultural production, especially as concerns organic farming:

1. **Incentive to utilize biochar in organic agriculture:** Since there are several beneficial impacts of biochar on the soil health and crop yields, the policy administrators should seek an incentive to use biochar as a sustainable and feasible soil amendment in organic agriculture. Subsidies on the production of biochar or funding of research on application of biochar in an organic system would motivate its large-scale use.
2. **Policies on Sustainable Soil Amendments**: The governments and the agencies concerning agricultural practices should have regulations that may promote the use of soil conditions friendly amendants such as biochar and compost in organic farming. This may entail giving guidelines on the application rates of biochar, their feedstocks, and environmental sustainability-related standards.
3. **Research and Development Support:** Further research of the impacts of long-term use of biochar in organic farming systems should be supported. The funding of research that will cater to the use of biochar in any crops, climatic conditions as well as soil types should take precedence as these research policies. The investigation of methods of making biochar at affordable cost would also help in improving the availability of biochar in organic farming.
4. **Fostering Soil Health as a Major Sustainability Indicator:** Governments can work into incorporating soil health into sustainability indicators on organic farming. Such programs in which farmers are pinned for bettering soil quality and long-term fertility by following sustainable ways such as the use of biochar-amended compost would drive more growers towards the system.

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Conflicts of interest

The authors have no conflicts of interest to declare

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