The Compatibility Effects of Biochar-Vermicompost Mixes on Crop Productivity

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Abstract: This study sought to establish the compatibility effects of biochar/vermicompost application on growth and yield of maize and cabbages. Biochar application rate was at 3 to 4% of soil weight. Biochar was mixed in various proportions to come up with treatments which were 100% vermicompost, 50/50% biochar: vermicompost, 75/25% biochar: vermicompost and 100% biochar. The experiment was repeated twice and arranged as a completely randomized design and replicated five times. The study established that maize yield increased with application of biochar from 25% to 50%. In the cabbage trial, comparable results in plant height, leaf numbers and final yield was obtained with 100% vermicompost application, 50% and 75% biochar inclusion. When biochar was applied at 100%, noticeable reduction in plant performance was noted. It is recommended to use biochar as a bio-fertiliser at 50/50% biochar: vermicompost in maize and cabbage production.

Key words: Biochar, vermicompost, crop productivity, compatibility.

1. Introduction

In most arid and semi-arid regions, large areas of cultivated soils are characterised by high sand and low organic matter contents which in turn negatively affects soil physico-chemical properties [1]. These problems are particularly intense in developing countries like Zimbabwe where more than 80% of the population of smallholder farmers still rely on traditional technologies and tools; mainly hand-held hoes, minimal use of animal traction and no tractors [2]. However, soil health is the foundation of vigorous and sustainable crop production. This is characteristic of the semi-arid tropics like Zimbabwe. As a potential solution, the use of biochar as a soil amendment has been introduced.

Biochar is a carbon rich material produced by different thermo-chemical biomass conversion process like pyrolysis. Pyrolysis is a dry carbonization technique typically operated at 400-800 °C [3]. The application of biochar to the soil has been shown to enhance the capacity of the soil to retain nutrients and lessen leaching [4]. Studies done by Githinji, L. [5] have revealed that addition of biochar increases soil porosity and aggregation. Biederman, L. and Harpole, W. S. [6] reported that biochar addition to the soil leads to increased above ground productivity, crop yield, soil microbial biomass, rhizobia nodulation, plant potassium concentration and total soil nitrogen. Jeffery, S., et al. [7] found a 10% increase in the mean yield of various crops. The percentage increases found in literature tends to differ and depends on various factors such as initial soil properties and biochar characteristics [8]. High applications of biochar have been reported to reduce yields [9].

A study by Carter, S., et al. [10] reported increases in above ground biomass after biochar additions to non fertilized soils. However, other studies have found...
that biochar increases the persistence of simazine herbicide. Despite the promotion of biochar as a soil amendment, its compatibility with other soil amendments such as vermicompost is currently unknown. Vermicompost is one of the soil organic amendments that has found its way into Zimbabwean fields and gardens and now that biochar is coming in, the compatibility of these amendments need determination. The study explored the effects of various biochar vermicompost mixes on the productivity of cabbage and maize in a pot trial.

2. Materials and Methods

2.1 Experimental Site

Two experiments were carried out at BUSE (Bindura University of Science Education) nursery and were repeated twice. BUSE is located at the coordinates: 17°18’58’’ S and 31°19’23’’ E. The two sites are located in agro-ecological region 11a of Zimbabwe [11] and receive about 800 mm rainfall per annum. The average temperature for both areas was 25 °C. The soil used at both sites was medium grained sands with a pH of 4.1 (CaCl2).

2.2 Experimental Details

Biochar used in the experiments were obtained from the pyrolysis of maize stova. Biochar/vermicompost mixes used in these experiments were in the proportions 50/50, 75/25 vermicompost/biochar and 100% biochar. The mixes were used to fill the pots. Maize fert (7% N, 14 P, 7 K) was applied at a rate of 300 Kg/ha. At topdressing, 5 grammes of ammonium nitrate (35.5%) was applied at a rate equivalent to 250 kg/ha. The experiment was arranged as a completely randomized design with five replications. The experiment was repeated twice over time. Watering was done at 50% moisture depletion calculated using the evaporation pan measurements relevant at each crop stage. For tomatoes the weekly fungicide sprays were done through alternating copper oxychloride and Dithane M45.

2.3 Data Collection and Analysis

The data from the two repeats of the same experiment were pooled together prior to analysis. The data was analysed according to the model:

\[ Y_{ij} = \mu + T_i + e_{ij} \]

Where \( \mu \) is the average mean, \( T_i \) means the treatment effects and \( e_{ij} \) is the error term.

Data on plant growth parameters were subjected to analysis of variance using Genstat Version 13. The least significant test (LSD (Least Significance Difference) 0.05) was used to separate treatment means of the measured parameters with significant differences.

3. Results and Discussion

3.1 Maize Leaf Number

The results indicate that biochar inclusion at 50% performed similarly to vermicompost but was significantly (\( p < 0.05 \)) higher compared to inclusion at 25% (Fig. 1).

3.2 Maize Yield

The same trend was observed on maize yield with biochar inclusion at 50% having the highest yield compared to the rest of the treatments (Fig. 2).

3.3 Cabbage Height

There was no significant variation in cabbage plant height when biochar is applied at 50% and 75% when compared to vermicompost alone (\( p > 0.05 \)). The application of biochar in cabbage production at 100% resulted in significantly reduced plant height (\( p < 0.05 \)) when compared with application of vermicompost alone or biochar at 50% and 75% (Fig. 3).

3.4 Cabbage Leaf Canopy

The cabbage leaf canopy diameter was similar at 50% and 75% biochar inclusion when compared with 100% vermicompost application (\( p > 0.05 \)). However, at 100% biochar application rate, there was a significant
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Fig. 1 Effect of various biochar/vermicompost mixes on maize leaf number.

Fig. 2 Effect of biochar vermicompost mixes on maize yield.

Fig. 3 Effect of biochar vermicompost mixes on Cabbage plant height.
reduction in the cabbage leaf canopy \((p < 0.05)\) (Fig. 4)

3.5 Cabbage Leaf Number

There was no significant difference in cabbage leaf numbers grown under vermicompost alone compared to 50% and 75% biochar application rate \((p > 0.05)\). A significant reduction in the number of cabbage leaves was noted when biochar was applied at 100% compared to vermicompost only and biochar application at 50% and 75% \((p < 0.05)\) (Fig. 5).

4. Discussions

The study focused at establishing the effect of Biochar/Vermin-compost application on growth and yield of maize and cabbages. Maize yield increased with increasing application of biochar from 25% up to 50%. This is in tandem with the results of other researches from elsewhere in the world [12, 13]. The noticeable higher performance in maize with increased biochar application could be attributed to the improved soil physico-chemical characteristics of the soil which include among other properties the capacity of the soil to retain nutrients, increased cation exchange capacity and lessened leaching. Vermicompost could be the supplier of the nutrients while biochar preserves them for crop usage. The results also serve to confirm the compatibility of the
two organic soil amendments on crop productions. The usage of the mixes may be limited to the 50% inclusion level as any further increase in biochar did not yield a proportional benefit.

This agrees with Yamato, M., et al. [14] who indicated that the mobile portion consists of biochar short-term effects, the resident portion carries its long-term effects which vary with concentration levels. Within the mobile portion, the organic part acts much like other degradable carbon sources (e.g. compost or detritus). It contains dissolved organic carbon and organic matter that is available to soil microbes. The availability of the organic matter for plant growth will depend on the quantities applied to the soil.

In the cabbages, there was a similar response in all parameters measured to vermicompost/biochar application, comparable results in plant height, leaf numbers and final yield were obtained with 100% vermicompost application, 50% and 75% biochar inclusion. When biochar was applied at 100%, noticeable reduction in plant performance was noted. This agrees with Verheijen, F., et al. [15] and Lehmann, J., et al. [16] who established that biochar helps in nutrient retention and cannot work on its own in nutrient supply. Biochar works in combination with other soil components such as soil microbes to improve the overall soil dynamics, the conditions in which plants grow over a long term. This allows for better plant nutrition, improved plant growth and yield and brings overarching benefits to agricultural soil productivity.

This was further confirmed by Vincent, V., Thomas, R. G., Chan, K. Y., Xu, Z. and Julie, M. [11, 17, 18] who noted that, one reason for the ability of Amazonian Terra Preta soils to maintain high fertility, compared to adjacent infertile soils, is their ability to retain nutrients.

Biochar has properties for high cation exchange capacity which allows it to retain positive ions in a form that is exchangeable. These positive ions, vital nutrients such as ammonium or potassium cations, are availed to plants when needed. This is so, because oftentimes when conventional fertilizers are applied to poor soils, the nutrients end up lost through leaching, weeds, or microbial activity before crops utilizes them.

5. Conclusion

It can be concluded from this study that the there are synergistic effects of mixing biochar and vermicompost with a limit of 50% inclusion rate with vermicompost in order to improve maize and cabbage productivity.

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