Effects of Flashed Carbonized© Macadamia Nutshell Charcoal on Plant Growth and Soil Chemical Properties

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1. Abstract

Research conducted in the Brazilian Amazon indicates that carbonized materials, such as charcoal, are responsible for the persistent fertility of soils known as Terra Preta. In the present study, we compared the effect of Flash Carbonized© macadamia nutshell charcoal with 22.5% and 6.3% volatile matter (VM) contents on vegetable crop growth in a volcanic Andisol and a highly weathered Ultisol. We conducted four greenhouse experiments with treatments of varying charcoal rates, lime, and mineral fertilizers. In the Andisol, we observed a significant negative effect of 22.5% VM charcoal on plant biomass production. Charcoal did not improve plant uptake of K and Ca, but N, P, and Mg uptake significantly decreased at the highest addition rate. While charcoal increased soil pH, N, and total organic C, cation exchange capacity (CEC) and soil P decreased with increasing rates of charcoal. In the Ultisol, treatments receiving 22.5% charcoal did not show any improvement in plant production. In a fourth experiment, we found that charcoal with a lower VM content (6.3%) significantly improved growth in the Ultisol, particularly when combined with chemical fertilizers. Our findings suggest that the type of charcoal and its VM content may affect its suitability as a soil amendment.

2. Background

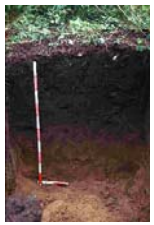


Photo source: University of Bayreuth

Figure 1. Soil profile of Terra Preta soil rich in organic carbon

- Maintenance of soil organic matter is a challenge in the tropics due to rapid rates of decomposition.
- In the Brazilian Amazon, high levels of soil organic matter and available nutrients persist in anthropogenic soils known as Terra Preta. Carbonized materials, such as charcoal, are responsible for the stability of soil carbon.
- Studies have shown that charcoal additions have an ameliorating effect on highly weathered tropical soils by increasing nutrient holding capacity and supply, and reducing soil acidity.[1,2]
- Flash Carbonization © technology at the Hawaii Natural Energy Institute permits rapid conversion of agricultural waste products to charcoal, which provides an opportunity for charcoal applications in agriculture.

3. Objective

- To demonstrate the effectiveness of macadamia nutshell charcoal additions on plant growth and soil properties in two Hawaiian soils
- To examine the suitability of two charcoal materials with different Volatile Matter (VM) contents

Figure 2. Agricultural lands on Maui

4. Methods

Figure 3. Soils amended with 4 rates of charcoal additions

Greenhouse Experiments

Exp 1: Lettuce was grown in an intensely cultivated, volcanic ash soil amended with 4 rates (0, 5, 10, and 20% w/w) of Flash Carbonized© macadamia nutshell charcoal (22.5 % VM content).

Exp 2: Corn was grown in an intensely cultivated, volcanic ash soil amended with 4 rates (0, 5, 10, and 20% w/w) of Flash Carbonized© macadamia nutshell charcoal (22.5 % VM content).

Exp 3: Corn was grown in a highly weathered, infertile soil amended with 0% and 5% Flash Carbonized © macadamia nutshell charcoal (22.5 % VM content), NPK + lime, and 5% charcoal + NPK +lime.

Exp 4: Corn was grown in a highly weathered, infertile soil amended with 0% and 10% Flash Carbonized© macadamia nutshell charcoal (22.5 % VM content), 10% Flash Carbonized Macadamia Nutshell charcoal (6.3% VM content), NPK + lime, and 10% charcoal (6.3% VM content) + NPK +lime.

Laboratory Analysis

Soils were analyzed at the Agricultural Diagnostic Service Center (ADSC) at the University of Hawaii, Manoa, for total organic C, total N, available P, and exchangeable cations using standard methods.

Plant tissue was analyzed for total nutrient content at the ADSC using standard methods.

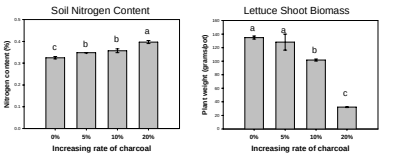
Statistical Analysis

Treatment effects were analyzed using analysis of variance (ANOVA) with randomized complete block design. Mean separation was performed using Waller Duncan groupings.

4. Results

Experiment 1

Figure 4. 0% charcoal (w/w) **Figure 5**. 20% charcoal (w/w)



Figures 6 and 7. Effect of charcoal on soil N and lettuce production

- Increasing charcoal additions resulted in a decrease in plant production, and uptake of P, Mg, N. There was no improvement in Ca and K uptake.
- Increasing charcoal additions resulted in a decrease in cation exchange capacity, soil P, K, Ca, and Mg, but an increase in soil N, C, and pH.

Experiment 2

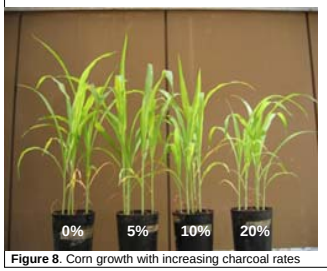


Figure 8. Corn growth with increasing charcoal rates

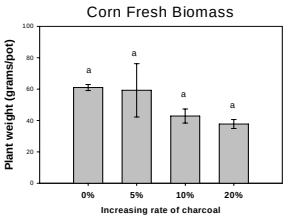


Figure 9. Effect of charcoal on corn production

- Increasing rate of Macadamia nutshell charcoal (22.5%) did not benefit corn growth

Experiment 3

Figure 10. Comparison of corn performance among treatments

Figure 11. Effect of charcoal on fertilized plants

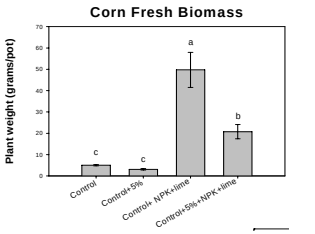


Figure 12. Effects of charcoal and fertilization on corn production

- 5% charcoal additions (22.5% VM) did not improve corn growth in highly infertile soil
- 5% charcoal additions (22.5% VM) reduced effectiveness of mineral fertilization

Experiment 4

Figure 13. Comparison between high and low VM charcoal

Figure 14. Combined effect of low VM charcoal and fertilization

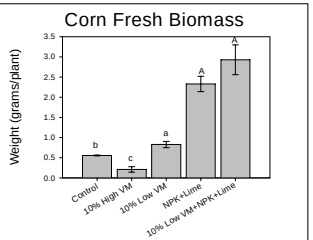


Figure 15. Effect of low and high VM charcoal and combined fertilization

- High VM charcoal (22.5%) reduced corn growth
- Low VM charcoal (6.3%) increased corn growth
- Low VM charcoal (6.3%) and mineral fertilization combination further increased corn growth

5. Discussion

- Macadamia nutshell charcoal with a VM content of 22.5 % did not improve, or had a detrimental effect, on plant growth in all four experiments.
- VM content is a measure of the susceptibility of charcoal to further decompose and form carbon, or further carbonize, when heated.
- Charcoal with high VM content is hydrophobic (Figure 16) and causes uneven water infiltration when added to soil (Figure 18).
- In contrast, charcoal with low VM content is hydrophilic (Figure 17) and permits uniform water infiltration (Figure 19).
- The differences in behavior among charcoal types influence its value as a soil amendment.
- Low volatile matter charcoal, such as 6.3%, may have a beneficial effect on plant growth, especially when combined with fertilizer.

Figure 16. Water repellency in high VM charcoal (22.5%)

Figure 17. Water absorption in low VM charcoal (6.3%)

Figure 18. Uneven water infiltration in soil amended with high VM charcoal (22.5%)

Figure 19. Uniform infiltration in soil amended with low VM charcoal (6.3%)

6. Conclusions

- Practices involving charcoal amendments appear to provide promising alternatives for increased carbon sequestration in soil and enhanced fertility of degraded land.
- However, our research shows that not all charcoal amendments are equally suitable for agriculture.
- While low VM (6.3%) charcoal shows potential for improving plant growth, particularly in combination with fertilizers, high VM (22.5%) charcoal has a harmful effect on plant growth and soil chemical properties.
- Differences in charcoal chemical properties, such as VM content, can reduce its effectiveness. However, more studies are needed to study the mechanisms causing this negative effect.
- Further research is needed to study the effects of high and low VM charcoal on biological properties and effects on plant root growth.

7. References

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8. Acknowledgements

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