Effect of volatile matter content in charcoal on soil biological properties

A.Tai McClellan[1], Jonathan Deenik[1], Russell Yost[1], Michael Jerry Antal, Jr.[2]

[1]Department of Tropical Plants and Soil Science, [2] Hawaii Natural Energy Institute
University of Hawaii at Manoa

1. Abstract

Volatile matter content is a property of charcoal which describes the degree of thermal alteration, or carbonization. Results of a series of greenhouse experiments conducted at the University of Hawaii have shown that plant growth is negatively affected by charcoals with high volatile matter content (20-35%) with or without fertilizer supplements, whereas low volatile matter charcoal (6-9%) increased plant growth when combined with fertilizer. The effect of volatile matter content in corncob charcoal on the overall hydrolytic enzyme activity and carbon and nitrogen dynamics was assessed during a 28-day laboratory incubation of a highly-weathered subsoil, with and without nitrogen additions. The results showed that high volatile matter charcoal increased the hydrolytic enzyme activity by more than 2-fold in soils without added nitrogen, and by 4-fold in soils receiving nitrogen. Extractable ammonium and organic carbon rapidly declined in high volatile matter charcoal treatments. In contrast, low volatile matter charcoal did not have a significant effect on hydrolytic enzyme activity or nitrogen dynamics, but maintained elevated levels of extractable organic carbon. Our results suggest that high volatile matter charcoal contains a bioavailable carbon source which stimulates microbial activity and inhibits inorganic nitrogen availability, whereas low volatile matter content does not appear to be readily available for microbial consumption. We conclude that volatile matter is an important property of charcoal which causes differential effects on soil biological properties and warrants further investigation. Our findings have considerable agronomic value since the immobilization of nitrogen observed under laboratory conditions serves as a possible explanation for the adverse effect of high volatile matter charcoal on plant growth reported in the previous short-term greenhouse studies. Further investigation is needed to evaluate whether the observed effects persist in the long-term.

2. Background

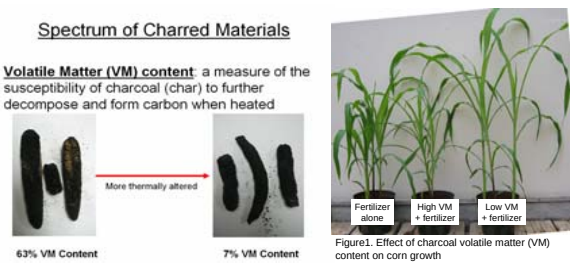

Figure1. Effect of charcoal volatile matter (VM) content on corn growth

3. Objectives

To determine the effect of charcoal volatile matter content on:

1. Soil carbon and nitrogen dynamics

2. Biological activity

4. Methods

Experimental Design

- 28-day incubation, 6 treatments in triplicate

Soil (acid subsoil) alone	Soil +Nitrogen (N)
Soil + high VM (34%)	Soil +high VM +N
Soil + low VM (7%)	Soil +low VM +N

- 8 sampling dates: Day 0, 1, 3, 7, 10, 14, 21, 28
  - Hydrolytic enzyme assay
  - Water extractable organic carbon
  - Ammonium-nitrogen
- Statistical Analyses
  - Proc Mixed, SAS 9.1
  - Repeated measures, unstructured

4. Results

1. Effect on Water Soluble Carbon

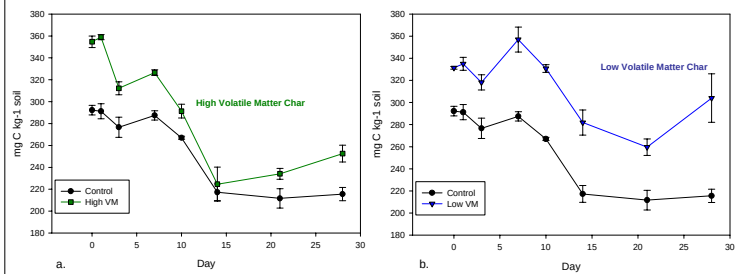

Figure 2. Effect of volatile matter on levels of extractable carbon. Soluble carbon declined more readily, as compared to the control, in high volatile matter charcoal treatments (a) within the first two weeks than low volatile matter charcoal (b).

2.Effect on Hydrolytic enzyme activity

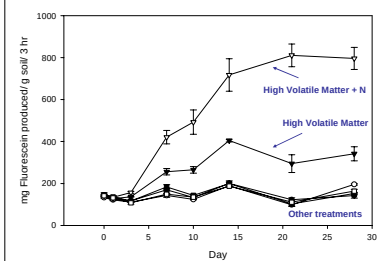

Figure 3. Hydrolytic enzyme activity doubled in high volatile matter treatments, as compared to the control and low volatile matter treatments, and more than quadrupled in soil receiving high volatile matter charcoal in combination with nitrogen.

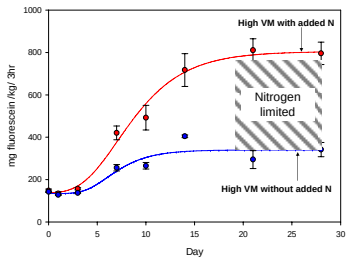

Figure 4. The increase in hydrolytic enzyme activity was nitrogen-limited. There was a greater exponential increase in activity in treatments receiving both high volatile matter charcoal and nitrogen (R^2=0.92) than charcoal alone (R^2=0.77). Curves fitted using Gompertz-Lay equation.

3. Effect on Ammonium Nitrogen

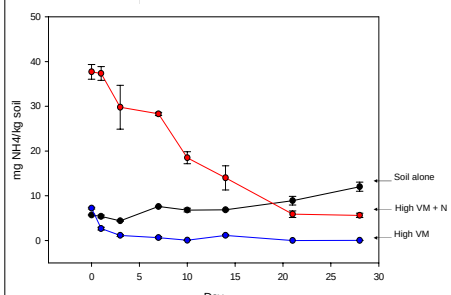

Figure 5. Extractable ammonium was depleted in soil receiving high volatile matter charcoal alone. All added ammonium was exhausted after three weeks in treatments receiving high volatile matter charcoal and nitrogen fertilization. Almost twice the amount of soluble carbon was depleted in high VM treatments. Low VM treatments maintained soluble carbon during first two weeks of incubation.

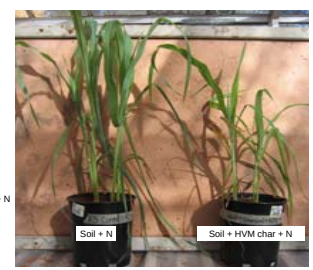

Figure 6. The immobilization of nitrogen in treatments receiving high volatile matter may help explain the negative effect of high volatile matter charcoal on plant growth observed in previous greenhouse experiments (of Spring 2007).

5. Discussion

- The degree of carbonization (VM content) significantly affects the chemical composition of corncob charcoals as shown in the GC-MS chromatograms 7a, b, and c.
- Corncob charcoals with high VM content (7b) provide bioavailable compounds which fuel microbial growth (Figures 8a and b).

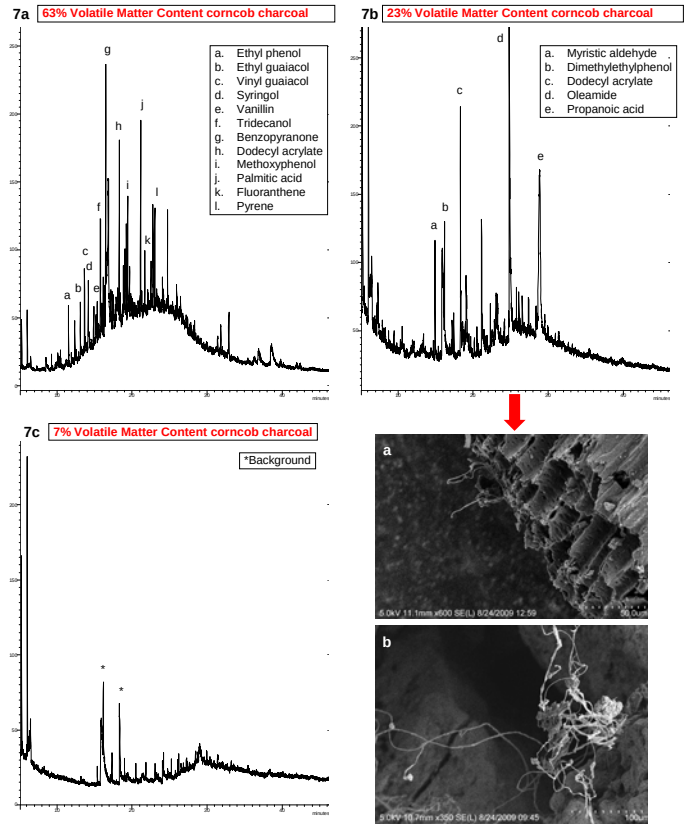

Figure 7. GC-MS chromatograms of a range of corncob charcoal materials with differing VM contents (a) 63%, (b) 23%, and (c) 7%.

Figure 8. SEM photographs of soils amended with 23% VM corncob charcoal (a) with fungal growth (b).

6. Conclusions

- High VM content charcoal
  - –Degradable carbon pool
  - –Stimulates microbial activity
  - –Promotes nitrogen immobilization in the short-term
- Low VM content charcoal
  - –No effect on microbial activity
  - –Contains inaccessible carbon source in the short-term

7. Acknowledgements

Many thanks to Dr. Goro Uehara for his guidance and Dr. Aminata Diarra and Yudai Sumiyoshi for their assistance. The Flash Carbonized ® charcoal was provided by Dr. Michael Antal and the Hawaii Natural Energy Institute. GC-MS work was generously provided by Dr. Sonia Campbell at the University of Hawaii Manoa.

Questions or Comments? For additional information, contact Tai McClellan:
3190 Maile Way, Plant Sci Bldg 102, Honolulu HI 96822 Email: amandatm@hawaii.edu Phone: (808) 956 2636