CARIBBEAN FOOD CROPS SOCIETY

50

Fiftieth
Annual Meeting 2014

St. Thomas, United States Virgin Islands
Volume L

PROCEEDINGS

OF THE

50TH ANNUAL MEETING

Caribbean Food Crops Society
50TH Annual Meeting
July 7 – July 11, 2014

Sugar Bay Resort and Spa Hotel
St. Thomas, United States Virgin Islands

Edited by
Thomas W. Zimmmerman, Stafford M.A. Crossman,
Errol Chichester and Wilfredo Colón

Published by the Caribbean Food Crops Society

ISSN 95-07-0410

Copies of this publication may be obtained from:

CFCS Treasurer
Agricultural Experiment Station
Jardín Botánico Sur
1193 Calle Guayacán
San Juan, Puerto Rico 00936-1118

Mention of company and trade names does not imply endorsement by the Caribbean Food Crops Society.

The Caribbean Food Crops Society is not responsible for statements and opinions advanced in its meeting or printed in its proceedings; they represent the views of the individuals to whom they are credited and are not binding on the Society as a whole.

Proceedings of the Caribbean Food Crops Society. 50:69-77. 2014

TURFGRASS GROWTH AND SOIL WATER STATUS IN RESPONSE TO BIOCHAR APPLICATION

Graham H. Belle and Francis B. Lopez, Department of Biological and Chemical Sciences, The University of the West Indies, Cave Hill Campus, BB11000, Barbados.
Email: francis.lopez@cavehill.uwi.edu

Abstract: Much research attention is currently focused on biochar (charcoal) as a soil amendment for enhancing plant growth while providing a mechanism for carbon sequestration. The extensive porous structure of charcoal can serve to increase mineral nutrient retention, microbial activity and water status in the soil medium for very long periods. Such effects can conceivably reduce the application frequency of fertilizers and irrigation water resulting in reduced costs along with environmental benefits. This is likely to be especially beneficial for turfgrass on rapid-draining sports fields, where maintenance costs can be considerable. Responses to the application of locally-sourced biochar (produced by traditional methods from local feedstock) were investigated for turfgrass (*Zoysia japonica* Steud., 'El Toro') grown in pots under field conditions. Observations on turf growth and soil water status were made for varying biochar application rates (0 - 20%, v/v of soil medium) using two types of biochar (plain, enriched), five application methods and three sand/soil potting mixtures. Enriched biochar was treated with compost tea from chicken manure during the production process. Enriched biochar enhanced turfgrass growth and soil moisture status when applied soon after product preparation but not after 6 months of dry storage. Effects of biochar application rates were observed only after 7 months of incubation in the soil medium, with increased turfgrass height at application rates of 4% or higher and optimum clippings dry mass production at 12% biochar. Soil incorporation appeared to work better than surface application of wet or dry biochar. Newly applied biochar had no significant effects on early turfgrass establishment in varying sand/soil potting mixtures. Biochar produced with traditional low-level technology appears to show potential as an organic input for sustainable production provided that there is an adequate soil incubation period.

Keywords: green cover, image analysis, greenness index.

INTRODUCTION

Biochar refers to the carbon-rich material produced by the pyrolysis of organic material (feedstock) under low oxygen conditions for use as a soil amendment. This organic input can remain in the soil for very long periods influencing soil physical and chemical properties while sequestering carbon dioxide from the atmosphere (Schmidt et al. 2014). The physical and chemical properties of biochar are affected by the nature of the feedstock and the pyrolysis temperature used in the production process (Lei and Zhang 2013). Biochar application can improve soil microbial activity, soil water retention capacity and saturated hydraulic conductivity (Lei and Zhang 2013). Positive effects on soil nutrient retention and bioavailability can occur due to the high porosity of the biochar particles, which increases the surface area for adsorption of ions (Scholz et al. 2014). Yield responses tend to increase over time after biochar application and are generally greater with biochar application on poorer soils (Andrew et al. 2013).

Beneficial agronomic and environmental effects of biochar as a soil amendment have been demonstrated, however, results are not always positive and there are numerous knowledge gaps (Verheijen et al. 2009).

The turfgrass industry stands to benefit greatly from the use of Biochar due to the frequent heavy demands for irrigation water and fertilizers, which can be costly and may also pose a drain on foreign exchange reserves along with environmental risks. Biochar can be applied to the root zone soil before turf establishment and/or later as a top dressing. Biochar application was found to increase water retention and reduce nitrogen leaching for turfgrass in sand-based systems, but root growth was reduced at high application rates (Brockhoff et al. 2010). Soil phosphorus and potassium levels also increased as the biochar application rate increased from 0 to 25% (v/v), suggesting that essential nutrients can also be supplied by the biochar (Brockhoff et al. 2010).

There appears to be potential benefits for use of biochar as a soil amendment in turfgrass, however, further investigations are required on biochar preparation, optimum application rates and methods and effectiveness in different soil types. Biochar prepared by traditional (low technology) methods appeared to show consistent yield increases when applied to soil (Spokas et al. 2012). In the current work, biochar prepared from local feedstock using traditional (drum) technology was applied to potting mixture for Zoysia (*Zoysia japonica* Steud., 'El Toro') turfgrass growing in pots. Objectives of this study were to investigate the effects of biochar preparation (with and without compost tea), application rates and methods, and treatment effectiveness in different soil types.

MATERIALS AND METHODS

Two types of biochar (plain and enriched) were produced for this study by a local company (Diceabed (Barbados) Ltd., Gibbons, Christ Church, Barbados). Plain biochar was produced by the pyrolysis of organic matter in a drum, using local green waste materials. The enriched biochar was produced by submerging plain biochar (prior to grinding) for three days in a container containing compost tea from chicken manure. The density of the plain and enriched biochar was 340 g L^{-1} and 406 g L^{-1}, respectively.

Three potted-plant experiments using Zoysia turfgrass were conducted under field conditions at the Cave Hill Campus of the University of the West Indies, Barbados during the period May 2013 to March 2014:

1. Experiment #1: Biochar types and application rates
2. Experiment #2: Biochar types and application methods
3. Experiment #3: Biochar application methods and soil types

In all studies, Zoysia turfgrass was planted using plugs (2.5 x 2.5cm) obtained from nursery grass established in trays. Soil (local black clay) used for the preparation of potting mixtures was obtained in the vicinity of the Cave Hill Campus. Plants received daily irrigation as needed and a fertilizer (3 g L^{-1}, NPK 24-8-16, Scotts Miracle-Gro products, Inc., USA) solution was applied every 2-3 weeks. Clipping was done at weekly intervals with plants clipped back to the rim of the pot or to a height of 3.5cm from the rim on each occasion. Data were analyzed using statistical software (GenStat Discovery edition, VSN International Ltd., UK).

Experiment #1: This study was done in PVC tubes, 16.2 cm diameter and 45 cm depth, covered at one end with perforated caps to form planting pots. Thirty (30) tubes were filled with a 1:1 sand/soil mixture to a height of 35 cm from the covered base of each tube. The remaining 10 cm at the top of the tubes was filled with the same 1:1 sand/soil mixture containing varying mixtures of biochar as indicated in Table 1.

Mixing of the biochar with the sand/soil medium was done in an open tray and 1 g of Triple Super Phosphate (TSP) was added to the mixture for each pot. A completely randomized design was used in this study with 3 replications. Observations were made over a 9-month period.

Experiment #2: Plastic plant pots (4L, 17.9 cm average diameter) were used in this study. There were nine treatments, which consisted of two biochar types (plain and enriched), and four application methods and the control:

1. Control (no biochar application)
2. Incorporated (biochar mixed evenly into soil)
3. Plugs (biochar applied in two cylindrical plugs within potting mixture)
4. Spread (biochar spread on surface and covered by thin layer of soil)
5. Watered (biochar mixed with water and applied to surface of soil)

Table 1. Biochar treatments in Experiment #1

Treatment #	Type of Biochar	Biochar Application Rate v/v %
1	Control	0
2	Plain	4
3	Plain	8
4	Plain	12
5	Plain	16
6	Plain	20
7	Enriched*	4
8	Enriched	8
9	Enriched	12
10	Enriched	16

* Enriched with compost tea from chicken manure

The application rate for biochar was standardized at 4% (v/v) for both biochar types in this study (experiment #2). For the 'Plugs' application method, biochar was added to two cylindrical holes created in the soil mixture with a syringe (13 cm long, 2.9 cm diameter) on opposite edges of the pot, 2 cm from the rim. Phosphate fertilizer (Triple Super Phosphate, TSP, 3 g per pot) was mixed into each soil mixture including the control. Pots were arranged in five randomized blocks. Observations were made over a 5-month period.

Experiment #3: This study was conducted in 4L plastic pots as for Experiment #2. Three biochar application methods (control, incorporated and watered) and three sand/soil mixtures (33, 50, and 67 % sand) were combined in a factorial design (nine treatments). Only the enriched biochar was used in this study, and this was applied at a rate of 4% (v/v). Phosphate fertilizer (Triple Super Phosphate, TSP, 3 g per pot) was mixed into each soil mixture as for Experiment #2. Pots were arranged in a randomized block design with four replications. Observations were made over a 2-month period.

Observations

The following turfgrass growth and soil parameters were determined:

1. Green cover (%)
2. Chlorophyll index (dimensionless)
3. Grass height (mm)
4. Dry mass of clippings (g $week^{-1}$)
5. Soil water content (%, v/v), Soil temperature (°C), Soil electrical conductivity

Green Cover

A digital Camera was used to capture images of the surface of each pot during the period 10:00am to 12:00 noon. Images were taken at a distance of 60cm from the pot at an angle of 70-80 degrees to the horizontal ensuring that the surface of the pot accounted for most of the area in the image. The photographs were all taken from the same side for each block, facing the direction of the sun to avoid any shadow of the camera on the grass. The images were processed using image analysis software (Assess 2.0, APS, USA) to determine the percentage green cover (%) of the area within each pot. Weeds and rocks were removed prior to taking images to reduce error. Observations were made at weekly intervals at one week after clipping.

Chlorophyll Index

A chlorophyll meter (FieldScout CM1000, Spectrum Technologies Inc., USA) was used to monitor the chlorophyll index of the grass in each pot over time. The meter was aimed at the turf surface from 0.5 m above at an angle of 70-80 degrees from horizontal. Ten measurements were taken at random locations in each pot, being careful to avoid the bare soil surface and the rim of the pot. The chlorophyll meter automatically generated the average of these 10 readings and this measurement was recorded. It was ensured that the ambient light was equal to or more than the minimum recommended by the instrument manufacturer when the readings were taken. Observations were made at weekly intervals between 10:00 am and 12:00 noon at one week after clipping.

Turfgrass Height

The height of the grass above the rim of the pot was measured using a modification of the rising disc technique (New Zealand Sports Turf Institute). The instrument consisted of a cylindrical rod (26 cm long, with mm measurement markings) placed through the center aperture of a compact disc (13.55g, 12 cm outer diameter, 1.5cm hole diameter). The cylindrical rod was threaded vertically into the center of the turf to the level of the rim of the pot. The compact disc was then dropped from a height of 10 cm on to the turf guided by the cylindrical rod. Turf height was measured from the point where the disc rested on leaf blades to the rim of the pot. Observations were made at one week after clipping with one measurement made in each pot.

Dry Mass of Clippings

Turf clippings were collected in brown paper bags and the dry mass was determined following drying in an oven at 80°C for four days. Samples were allowed to cool within sealed plastic bags for several hours before dry mass was measured.

Soil Moisture, Soil Temperature and Soil Electrical Conductivity

Soil moisture, soil temperature and soil electrical conductivity were measured in the top 5cm of soil mixture using a multi-sensor probe (model 5TE, Decagon Devices Inc., USA). The three-prong probe was pushed into the soil at two locations in each pot and measurements were done 10:00 – 11:00 am and 5:00 – 6:00 pm.

RESULTS AND DISCUSSION

In experiment #1, there were strong effects of biochar type on turfgrass growth, chlorophyll index and soil moisture content within the first three months after planting (Table 2). Ground cover, chlorophyll index, turf height and soil moisture content were all higher in the enriched biochar compared to the plain biochar treatments. There were no significant effects of the biochar rate or of factor interactions (biochar type/rate/time) during this initial period. The enriched biochar infused with compost tea from chicken manure was likely to contain higher levels of nutrients and/or biostimulants compared to the plain biochar. The use of biochar produced from the pyrolysis of chicken manure has been shown to increase both soil macro and micronutrients (Hass et al. 2012).

Table 2. Results of repeated-measures ANOVA (p values) for parameters determined within three months after planting of turfgrass in soil mixtures with varying application rates of two types of biochar.

Parameter	Source of variation		
	Biochar Type	Biochar Rate	Biochar Type.Rate
Ground Cover (%)	0.026	0.386	0.064
Chlorophyll Index	<0.001	0.492	0.205
Turf Height (mm)	<0.001	0.073	0.259
Soil Moisture (%)	0.018	0.164	0.128

After 8 months (236 and 255 days after planting) in experiment #1, turf height at one week after clipping was consistently increased by Biochar rates of 4% and higher (Figure 1). Earlier measurements indicated no consistently significant effects of biochar application rate on turf height in conformity with results obtained during the first three months of growth (Table 2). These results suggest that a period of incubation in the soil is required after application of biochar before beneficial responses are observed. Biochar produced at relatively low temperatures (as used in this study) are likely to contain higher levels of plant oils that promote hydrophobicity in the short run but may serve to increase microbial activity and fertility over time (Verheijen et al. 2009). The observed effects of applied enriched biochar during the first three months may have been due primarily to the effects of compost tea from chicken manure on the soil medium. Significant effects of the enriched biochar were also observed at 7-8 months after planting in this study.

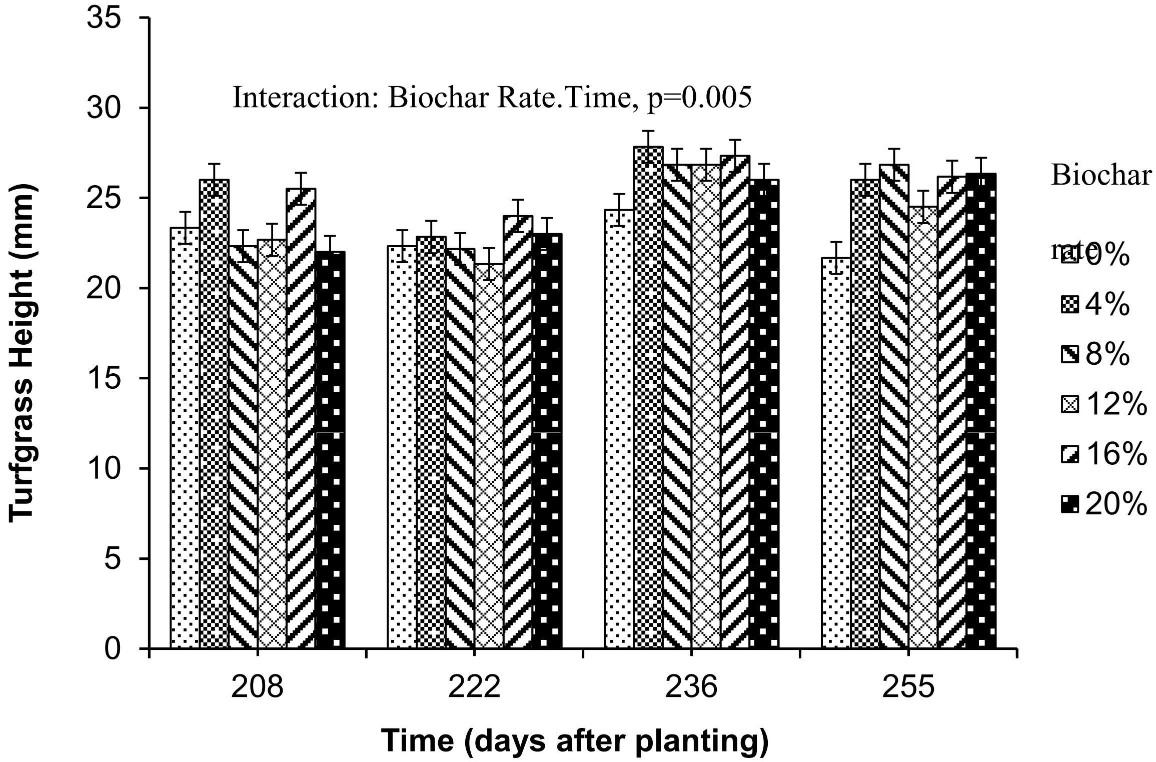

Figure 1. Effects of biochar application rate on turfgrass height (mean ±SE, at 1 week after clipping) for observations at various times after biochar application and planting.

Dry mass of clippings obtained per week was affected by both the type and rate of biochar applied for observations at 7-8 months after biochar application (Figure 2). Dry mass of clippings was consistently higher with use of the enriched biochar compared to the plain biochar. A significant quadratic trend was observed as biochar application rate increased and the highest dry mass of clippings was obtained at a biochar application rate of 12% (v/v of soil) for both types of biochar (Figure 2). If this optimal rate is scaled up, the biochar required per unit land area works out to be about 40 t ha-1 and 48 t ha-1 for the plain and enriched biochar, respectively, assuming that biochar is incorporated to a depth of 10 cm. This high rate is not likely to be practical and a lower application rate (4% v/v) was selected for follow-up studies investigating the efficacy of different application methods.

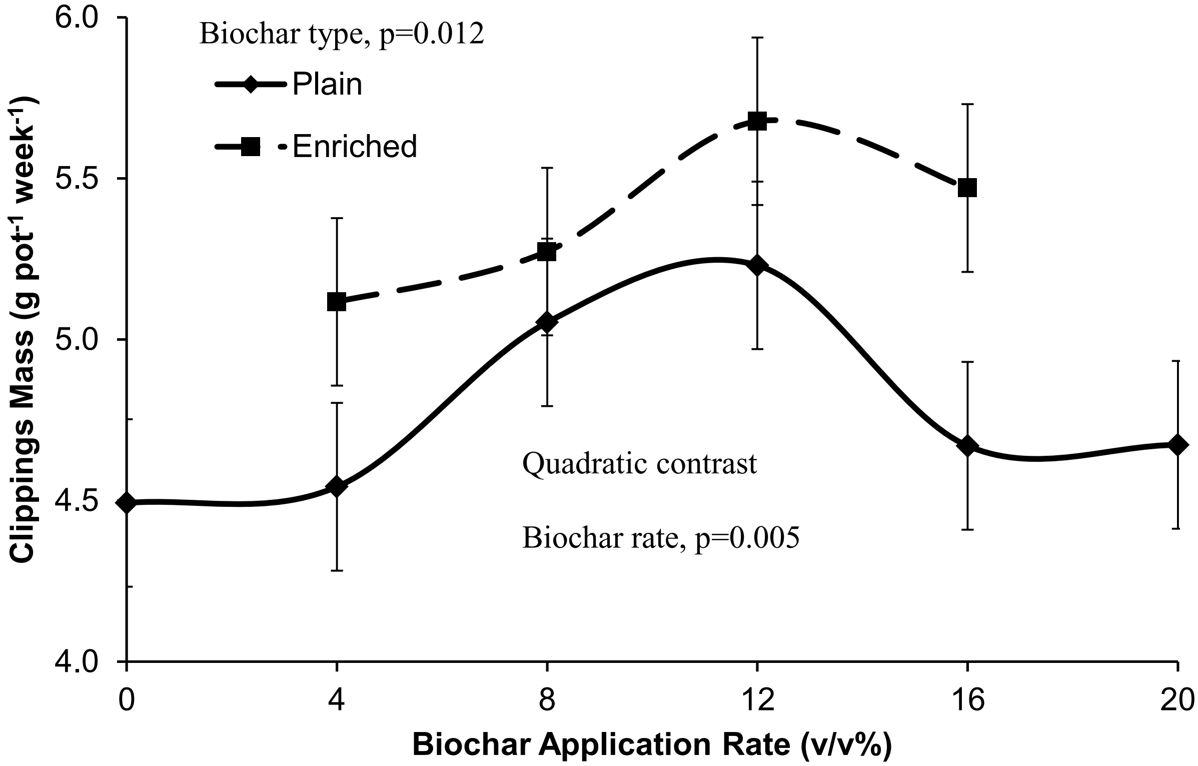

Figure 2. Effects of biochar type and application rate on dry mass of clippings (per week, means ±SE) observed 7-8 months after biochar application at planting.

The effects of biochar application in experiment #2 were marginal. There were significant effects of the biochar application methods on chlorophyll index measured during the first 3 months of turfgrass growth (Figure 3).The application of biochar by mixing into the soil (incorporated) appeared to be more effective than dry (spread) or wet (watered) applications to the surface. However, chlorophyll index for each of the 4 application methods tested was not significantly different from that of the control (Figure 3). Similar responses were also observed for dry mass of clippings and turfgrass height (data not shown). No significant effects of biochar type (plain vs. enriched) were observed in experiment #2. Perhaps beneficial biostimulant agents that may have been originally in the enriched biochar (freshly prepared) did not survive the months of dry storage.

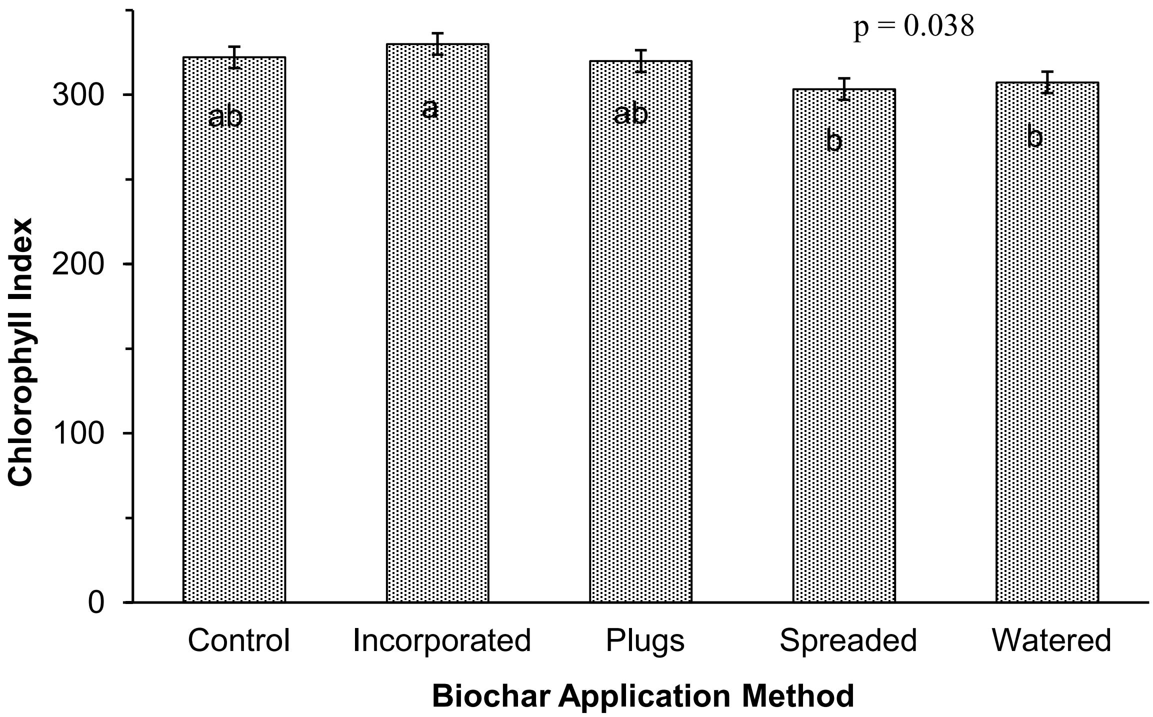

Figure 3. Effects of biochar application method on chlorophyll index of turfgrass measured over a 3-month period (data were pooled across time).

In experiment #3, turfgrass growth during the 3-month period after planting was reduced as the sand content was increased in the sand/soil mixture, however, there were no significant effects of biochar application (data not shown). Additional studies are needed to determine whether turfgrass establishment can be improved by biochar if planting is delayed for a few months after the biochar is applied to the soil.

CONCLUSIONS

Beneficial effects of biochar on turfgrass growth were observed after an incubation (aging) period of 7-8 months in the soil. The optimum biochar application rate was 12% (v/v of soil). Earlier responses to applied biochar are likely to be obtained with the application of freshly-prepared biochar enriched by treatment with compost tea. Soil incorporation of biochar appeared to be marginally better than surface application (dry or wet) methods. For established turfgrass, biochar application to fill cylindrical holes (plugs) created by soil aeration tines may be preferred compared to surface application.

ACKNOWLEDGEMENTS

The technical assistance of Mr. Jeff Chandler is gratefully acknowledged.

REFERENCES

Andrew, Crane-Droesch, Abiven Samuel, Jeffery Simon, and S. Torn Margaret. 2013. "Heterogeneous global crop yield response to biochar: a meta-regression analysis." *Environmental Research Letters* 8 (4):044049 (8pp).

Brockhoff, Shane R., Nick E. Christians, Randy J. Killorn, Robert Horton, and Dedrick D. Davis. 2010. "Physical and Mineral-Nutrition Properties of Sand-Based Turfgrass Root Zones Amended with Biochar." *Agron. J.* 102 (6):1627-1631. doi: 10.2134/agronj2010.0188.

Hass, Amir, Javier M. Gonzalez, Isabel M. Lima, Harry W. Godwin, Jonathan J. Halvorson, and Douglas G. Boyer. 2012. "Chicken Manure Biochar as Liming and Nutrient Source for Acid Appalachian Soil." *J. Environ. Qual.* 41 (4):1096-1106. doi: 10.2134/jeq2011.0124.

Lei, O., and R. D. Zhang. 2013. "Effects of biochars derived from different feedstocks and pyrolysis temperatures on soil physical and hydraulic properties." *Journal of Soils and Sediments* 13 (9):1561-1572. doi: DOI 10.1007/s11368-013-0738-7.

Schmidt, Hans-Peter, Claudia Kammann, Claudio Niggli, Michael W. H. Evangelou, Kathleen A. Mackie, and Samuel Abiven. 2014. "Biochar and biochar-compost as soil amendments to a vineyard soil: Influences on plant growth, nutrient uptake, plant health and grape quality." *Agriculture, Ecosystems & Environment* 191:117-123. doi: http://dx.doi.org/10.1016/j.agee.2014.04.001.

Scholz, Sebastian B, Thomas Sembres, Kelli Roberts, Thea Whitman, Kelpie Wilson, and Johannes Lehmann. 2014. Biochar Systems for Smallholders in Developing Countries: Leveraging Current Knowledge and Exploring Future Potential for Climate-Smart Agriculture. Washingtion, D.C.: World Bank Publications.

Spokas, Kurt A., Keri B. Cantrell, Jeffrey M. Novak, David W. Archer, James A. Ippolito, Harold P. Collins, Akwasi A. Boateng, Isabel M. Lima, Marshall C. Lamb, Andrew J. McAloon, Rodrick D. Lentz, and Kristine A. Nichols. 2012. "Biochar: A Synthesis of Its Agronomic Impact beyond Carbon Sequestration." *J. Environ. Qual.* 41 (4):973-989. doi: 10.2134/jeq2011.0069.

Verheijen, F. G. A., S. Jeffery, A. C. Bastos, M. van der Velde, and I. Diafas. 2009. Biochar Application to Soils - A Critical Scientific Review of Effects on Soil Properties, Processes and Functions. EUR 24099 EN, Office for the Official Publications of the European Communities, Luxembourg.