Sonoma Biochar Initiative

Building Healthy Soils
Redirecting Carbon

SONOMA ECOLOGY CENTER

2013 Sonoma Biochar Initiative Citizen Science Project Final Report

Funded by The Mental Insight Foundation

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I) Executive Summary

- The Sonoma Biochar Initiative (SBI), a project of the Sonoma Ecology Center since 2011, educates the public about the many advantages of using biochar, a soil amendment. In January 2013 SBI received a $15,000 grant from the Mental Insight Foundation to expand a pilot Citizen Science Project it had conducted in 2012, using home, school, and community gardeners to test the effects of using biochar in local soils.
- The purpose of the study was to educate and engage the public in the use and benefits of using biochar in their gardens, to test biochar in a range of local soils and with a range of plant types, and to give community members a chance to participate in a citizen science project valuable to SBI's and SEC's mission.
- SBI distributed free 5-gallon bags of biochar and compost, mixed 50/50, to 183 participants in Sonoma, Marin, San Francisco and Alameda counties, along with directions on measuring plant growth over a five month period using a photo monitoring protocol. A data sheet was also provided for those wanting to record additional observational data.
- Participants were instructed to prepare two identical 3' X 3' plots in a previously un-amended section of their garden—a Control plot with just compost and a Treatment plot with the biochar/compost blend we provided—and to use the same plant types in each. They were then instructed to photograph the plots at 4 intervals during the study and to submit these to our project scientist, Rebecca Lawton, for analysis.

Project Results

1. Results showed a range of increase between 7 and 40 times greater plant growth in Treatment plots over Control plots, depending on the month the photos were submitted. The smallest growth differences in Treatment over Control were shown in the first month (7 to 9 times) and the greatest in month four (33 to 40 times).
2. Our primary goal of engaging a large number of area gardeners in the use of biochar was achieved. Though only 30% (55 people) of 183 participants to whom we distributed bags actually submitted some data over the life of the project, another 18% (33 people) responded in the post-project survey that they had used biochar in their garden but did not submit any data. A majority of these 88 people reported good results with biochar and will likely recommend its use to others. This word-of-mouth networking will be critical in increasing acceptance for biochar at this early stage of its market development.
3. Not all participants showed positive results. While there were 54 reports of increased growth over the five-month study period (76 percent of total submissions), 14 additional reports showed no growth differences between the Control and Treatment plots, and 3 reports had less growth in the Treatment plots.

Project Benefits

There were tangible as well as intangible benefits from this project:

- We received positive growth results with biochar and compost use in the vast majority of garden plots for which we received data.
- We successfully promoted the use of biochar as a new soil treatment to improve soil health, improve nutrient and water retention, and sequester carbon safely.
- We enabled community participation in a citizen science study with relevance and meaning.
- We provided an opportunity for high school and elementary school students to engage in a healthy, educational, hands-on agricultural learning activity.
- We gave participants a sense of hope and a positive experimental activity that may help address climate change in the future, one garden at a time.
- We provided another example of a doable, scalable community project with impact.
- We collaborated with other groups dedicated to gardening, environmental protection, and soil restoration, introducing them to biochar in the process.

II) Project Background

Biochar is a specialized form of charcoal that is suitable for use as a soil amendment (typically combined with compost) to enhance soil health, increase agricultural crop yields, and conserve nutrients and water. Biochar is able to fulfill these functions due to its unique physical structure (see below), with literally millions of tiny pores able to hold nutrients, water and microbes for the plants' roots to access and enjoy. In many ways it is akin to a coral reef in the ocean, acting as a natural attractant, sanctuary, and incubator in soil by creating infrastructure in which billions of organisms can thrive.

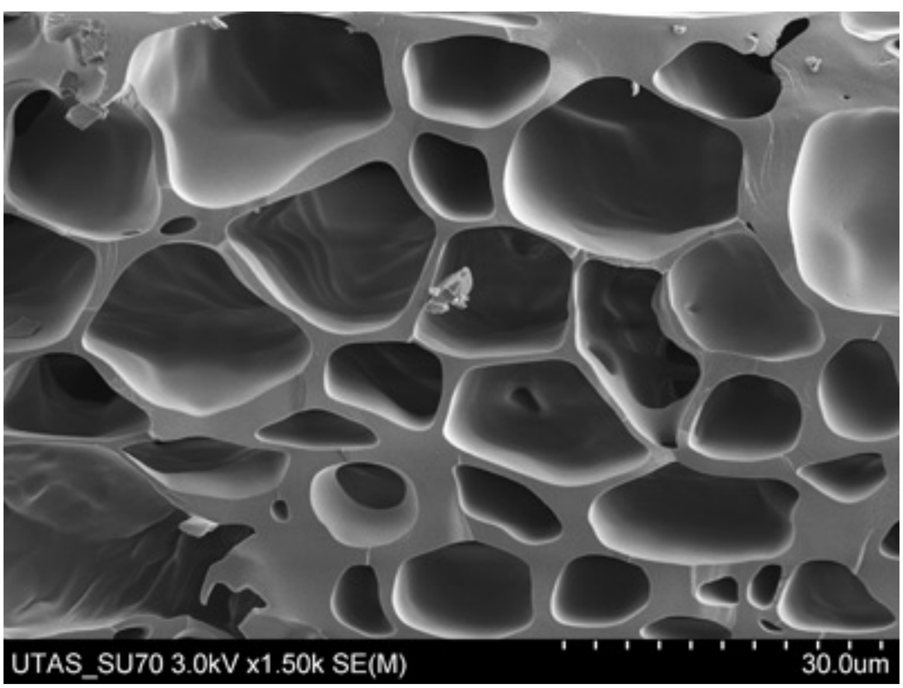

Photo I (Microscopic photo showing biochar's porous structure)

Biochar is made by heating woody waste materials (of many different types) in the absence of oxygen, in a process called "pyrolysis." The wood is not burned, but at temperatures of about 450 to 700 degrees C gases are produced from the wood that feed the pyrolysis process, leaving behind essentially pure carbon with its millions of microscopic pores.

Ancient, fertile soils found in large swaths of the Amazon rainforest, called "terra preta" or dark earth, have been shown to be highly productive when compared to crops grown in the surrounding soils. The discovery of these highly fertile soils, thousands of years after they were made, and their subsequent analysis showing that they contained large amounts of charcoal (biochar), helped spawn a nascent global biochar industry over the last 10 years. While there is still much to learn about how and why these dark earth soils were made, the fact that the charcoal has remained in the soil for centuries, helping to build a highly fertile soil web while sequestering carbon in a safe and beneficial way, has energized a growing list of scientists, academics, technologists, environmentalists, farmers and gardeners to explore its use.

Biochar holds particular promise for farmers in improving their waste management practices, lowering nutrient input costs, reducing water use, improving crop productivity, reducing C02 emissions, and even production of renewable energy for the farm.

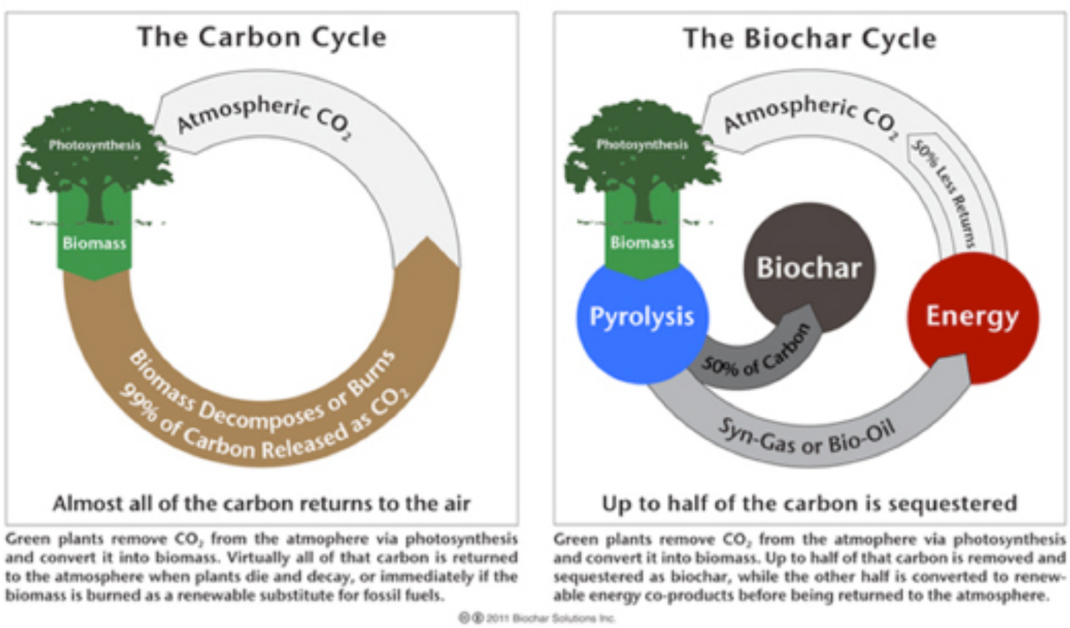

Illustration I   Pyrolyzing waste materials can produce a number of valuable products along with biochar while removing atmospheric C02 from the carbon cycle.

This industry, however, remains in a very early stage of development. Currently there is a low commercial demand for biochar, primarily due to a lack of awareness about its many benefits and its currently high cost. In looking for ways to increase this awareness and help create demand for biochar in our local community SBI came across a citizen science project in the UK called "The Big Biochar Experiment," and started an email dialog with one of its founders, Dr. Cecile Girardin.

After obtaining permission to use this project's model and data sheet as a guide, in 2012 SBI launched a small pilot program in Sonoma that had limited but promising success. A grant from the **Mental Insight Foundation** allowed us to expand the project in 2013. SBI contracted with Sonoma Ecology Center scientist Rebecca Lawton to redesign the project protocol, collect and classify the data, and analyze it.

Specific Project Objectives:

- Engage as many local people as possible in the use of biochar. Given the general lack of awareness of biochar in our community, this was our number one objective. Since biochar needs to be conditioned before use with nutrients such as nitrogen and phosphorus to increase its immediate effectiveness in soil, our specific goal was to distribute at least 200 bags of a biochar/compost mix to individual participants and organizations.
- Gather data on plant success from participants in a format that could be reported and analyzed in a meaningful way (primarily through photo monitoring).
- Provide individualized support for participants to answer their questions and provide reminders for data collection.
- Coordinate efforts with The Big Biochar Experiment in the UK to compare data and results.
- Survey participants at the end of the project on their experience.
- Conduct outreach and publish results of the project to increase overall public awareness of biochar's benefits.

III) Project Results in Summary

A total of 233 bags of biochar mixed with compost were distributed to 183 individuals, schools, and community gardeners between April 15, 2013 and June 15, 2013. Detailed instructions were included for planting to compare the impacts of using the biochar/compost mixture with similar plants using regular compost alone; photographing results at monthly intervals; and submitting the camera files via email to the Sonoma Ecology Center. A separate two-sided data sheet was included for those that wanted to measure their water use footprint and plant weight differences, and submit additional notes.

Participants were reminded via email when to take their photos and submit them, and when to turn in their data sheets.

Of the 183 participants who received bags, 55 submitted at least some useable data during the five-month study— either photographs, written observations, or both. This response rate represents only 30% of the total number of project participants. Nevertheless, Rebecca Lawton, the Sonoma Ecology Center scientist who analyzed the data, said: "On the whole though, we did very well. This is one of the best outputs from citizen science I've ever seen."

According to Dr. Girardin, Principal Investigator for the Big Biochar Experiment in the UK, they distributed 344 bags of biochar, 73 reported carrying out the experiment, and 44 participants sent in data over the 1.5-year project, of which 38 were deemed useable for their study.[1]

As with many citizen science projects that rely on volunteers, participation dwindled over the life of the study. A total of 44 people submitted photos in May, 37 submitted photos in June, 26 submitted photos in July, and 21 submitted photos in September, the final month of the study when data sheets were also requested. Eight participants submitted completed data sheets (or in some cases hand written or typed results) during the study period. This small number of data sheets did provide important additional empirical data.

The quality of the data that was obtained was robust and relevant. Results clearly showed that overall the biochar-treated plots exhibited improved growth characteristics of most of the plant types used when compared to the non-treated control plots.

1. Mean observed growth was 7 and 9 times original plant size for Control and Treatment, respectively, in June; 18 and 23 times for Control and Treatment respectively in July; and 33 and 40 times for Control and Treatment respectively in September.

2. Only one site showed no difference in growth between its Control and Treatment plots in June; this jumped to 6 sites in July but then diminished to 4 in September. The number that showed less growth in Treatment plots compared to Control plots equaled 4, 2, and 0 in the three months, respectively. The number that showed greater growth in Treatment plots compared to Control plots was clearly much higher, at 23, 15, and 16 sites in June, July, and September. In sum, using the biochar/compost mixture did make a difference in the vast majority of cases.

3. Overall, the amount of plant growth shown in Treatment plots exceeded growth in their Control plots by 142 percent in June (1.42 times more in Treatment over Control), 143 percent in July (1.43 times more in Treatment over Control), and 135 percent by September (1.35 times more in Treatment over Control).

Below are two charts showing the comparison in growth between the Treatment and Control plots over the study period for those who submitted photos. (Some people submitted only once, some twice, and some three times.)

Girardin, Cecile Dr. Cecile Girardin - The Big Biochar Experiment. 26 January 2014 <http://www.youtube.com/watch?v=pNM4CNiSeKE>.

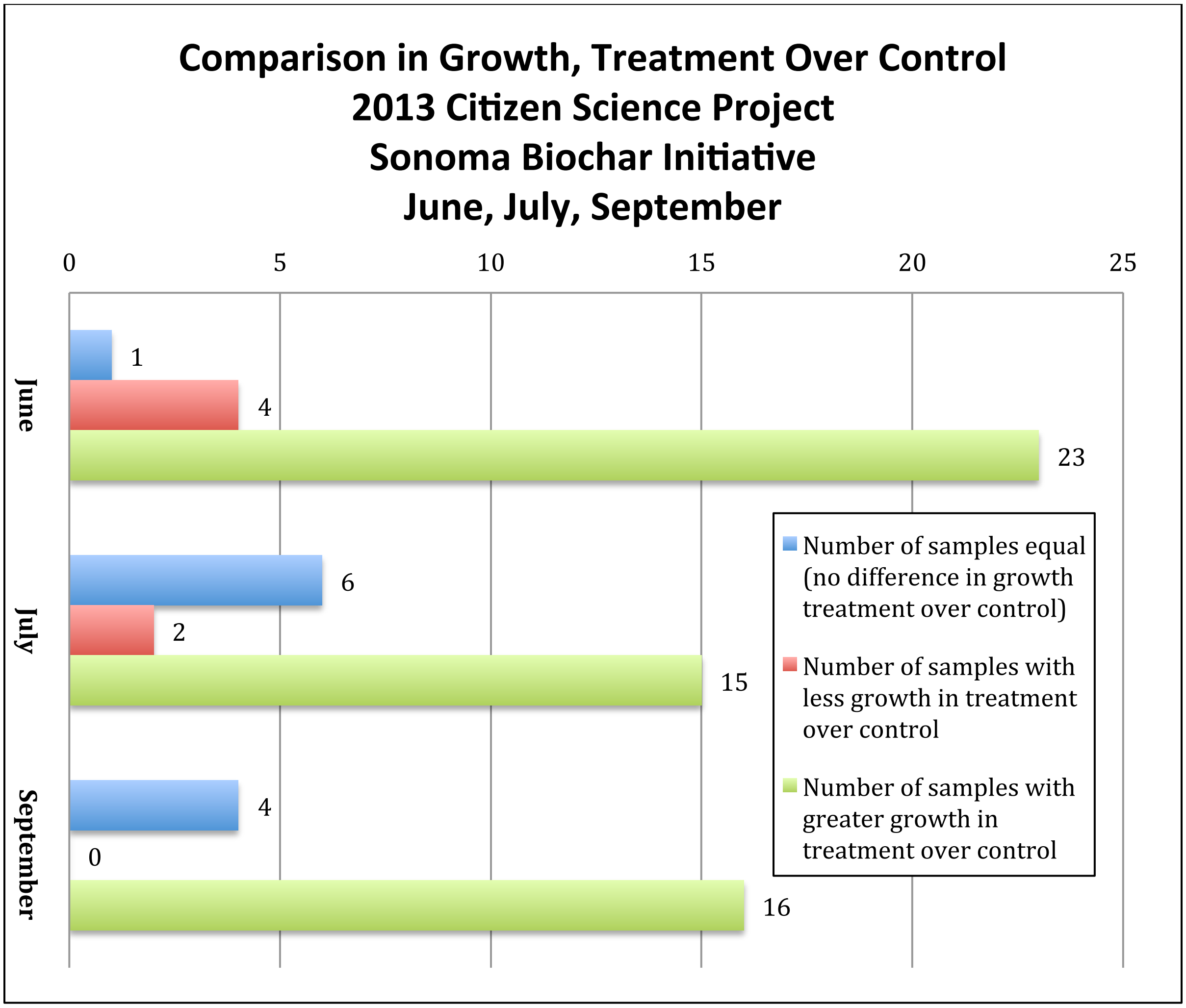

Chart I

It is important to note that, as shown in Chart 1 above, while there were 54 reports of increased growth over the five-month study period (76 percent of total reports), 14 additional reports showed no growth differences between the Control and Treatment plots, and 3 reports had less growth in the treatment plots. A citizen science experiment like this study clearly has many variables that were out of our control, including how the plots were prepared, soil health and condition at time of planting, exact plant types used, watering variability, possible shading differences between plots, additional nutrients added, disease or insect/snail infestation, pesticides applied this year or in previous years, etc. As a result, it is unknown what may have actually caused this variability of plant responses to the treatment. These results could have resulted from one or a combination of these factors.

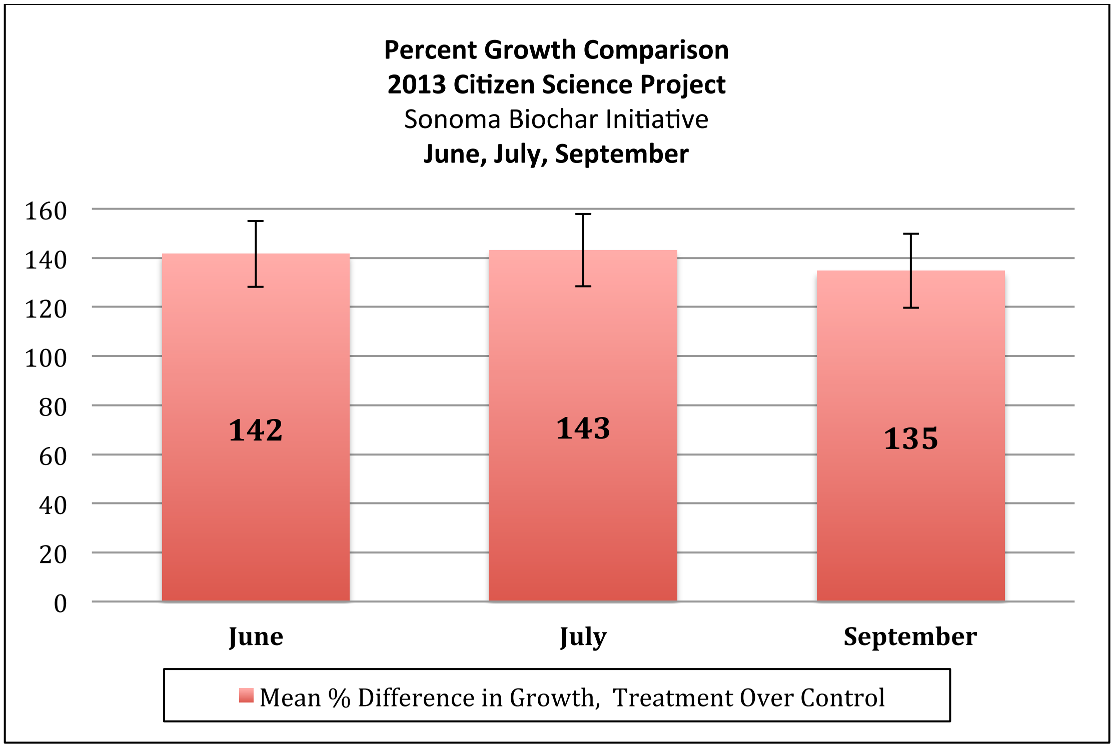

Chart II

Overall, the difference between plant successes in the plots treated with biochar over the control, as measured by visual growth recorded by our study participants, was remarkable. While there was a measure of subjectivity in the analysis, and this was not a peer-reviewed scientific study, we feel confident that we received enough data from responsible citizen scientists that similar results could be obtained by others in the future.

Again, it is important to note that positive results were not universal, and that a number of results showed no difference between the plots, or even showed negative results. Much more research needs to be done on how biochars, made from specific feedstocks, at certain temperatures, blended with certain nutrients, used in certain soils, with certain plants, produce positive or negative results. This research will likely lead to the formulation of biochar products targeted for specific purposes—a development that will help biochar's acceptance into mainstream agricultural use.

IV) About Biochar

Charcoal (and when used in agriculture, biochar) has been made for thousands of years using pits or trenches dug in the ground or aboveground earthen structures. Modern technologies offer much cleaner, more efficient methods of production with much fewer emissions and a higher-quality end product. Biochar's wide adoption in agriculture is just emerging globally as more and more peer-reviewed scientific studies document its advantages, and farmers slowly discover its use as a means of increasing the production of some crops, building soil health, and better managing waste resources.

The International Biochar Initiative (IBI) provides a general definition of biochar.[2]

> **Biochar is a solid material obtained from the carbonization of biomass. Biochar may be added to soils with the intention to improve soil functions and to reduce emissions from biomass that would otherwise naturally degrade to greenhouse gases. Biochar also has appreciable carbon sequestration value. These properties are measurable and verifiable in a characterization scheme, or in a carbon emission offset protocol.**
>
> **This 2,000 year-old practice converts agricultural waste into a soil enhancer that can hold carbon, boost food security, and increase soil biodiversity, and discourage deforestation. The process creates a fine-grained, highly porous charcoal that helps soils retain nutrients and water.**
>
> **Biochar is found in soils around the world as a result of vegetation fires and historic soil management practices. Intensive study of biochar-rich dark earths in the Amazon (terra preta), has led to a wider appreciation of biochar's unique properties as a soil enhancer.**
>
> **Biochar can be an important tool to increase food security and cropland diversity in areas with severely depleted soils, scarce organic resources, and inadequate water and chemical fertilizer supplies.**
>
> **Biochar also improves water quality and quantity by increasing soil retention of nutrients and agrochemicals for plant and crop utilization. More nutrients stay in the soil instead of leaching into groundwater and causing pollution.**

Scientific research, as well as empirical observations and testing of the terra preta (dark earth) fields in the Amazon areas mentioned above, indicates that biochar (recalcitrant carbon) resists degradation in soil and can persist in soil for hundreds or thousands of years. Scientific testing, however, has shown a staggering variance of biochar's persistence in soil, which can range from "5 to 8,000 years," according to soil scientist Dr. Johannes Lehmann of Cornell University.[3] Persistence can depend on a number of factors, including the type of feedstock used, the temperature of the pyrolysis process that can vary from 450 to 700 degrees Celsius, the particle size of the biochar, etc. Clearly, much

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2 International Biochar Initiative. Bibliography. 10 February 2014 <http://www.biochar-international.org/biblio>.

3 Lehmann, Dr. Johannes. USBI Biochar Conference. Amherst, Mass. 14 October 2012.

more research needs to be done to fully understand this process. Nevertheless, studies indicate that as much as 1.8 gigatons of carbon could be sequestered globally annually through widespread biochar applications.[4]

Commercial products such as the biochar itself and its production byproducts -- synthesis gases, bio-oil, and process heat -- can be created in larger or lesser amounts depending on the biochar production technology being used. As stated previously (and as verified by our citizen science project) application of conditioned biochar to topsoil has been shown to positively influence plant productivity.[5]

Global research shows that as a soil amendment, biochar improves the pH balance in certain soils, increases tilth, and decreases compaction. This combination of positive effects allows for improved oxidization and provides critical habitat for soil microbes and mycelium that secure nutrients for plants. Nutrient retention reduces or eliminates the need for chemical fertilizers while reducing the mineral runoff thereby improving water quality. Biochar's moisture retention ability reduces the need for irrigation water and related electricity/energy demand.

Realizing these multiple environmental and economic benefits from biochar use requires its broad adoption across both agricultural and gardening sectors of an agricultural community. While use of biochar is promising, several factors currently limit its widespread adoption, including cost, lack of awareness regarding its benefits to agriculture, and limited experience with site-specific implementation. This Citizen Science Project was designed to begin to address some of these issues.

V) 2012 SBI Citizen Science Project

As part of this outreach, SBI conducted a small citizen science pilot project in Spring 2012 to engage the public in the use of biochar in backyard gardens in the Sonoma area. Patterned after the Big Biochar Experiment in the UK, a similar project created by Dr. Cecile Girardin of Oxford University, SBI was granted permission to use Dr. Girardin's experimental model and data sheets for use in its project.

With assistance from students from the Ecology Club at the Sonoma Valley High School and SBI members, 50 bags of biochar and compost were filled and 30 ultimately distributed for free to local gardeners who responded to an email soliciting participants for the study.

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[4] Woolf, Dominic. Biochar as a soil amendment: A review of the environmental implications. January 2008.

[5] Hardy Schulz, Gerard Dunst, & Bruno Glaser. "Positive effects of composted biochar on plant growth and soil fertility." Agronomy for Sustainable Development 33.4 (2013): 817-827.

Members of the Sonoma Valley High School Earth Club (including Advisor Mr. Gissell (right) and SBI member Ray Gallian prepare to distribute the biochar and compost.

Photo II High school students and SBI members distribute biochar in front of Sonoma Valley High School.

Also distributed were instructions for preparing and planting two 3' X 3' plots—one serving as the Control area with just compost and the other Treatment area with the biochar/compost mix. Participants were asked to use the same plant types in each plot and to record visual evidence and observations about their growth, including plant size, flowering, and fruiting. At the end of the growing season they were asked to weigh the plants in each plot, record this information, and return it via regular mail or email.

While SBI did receive encouraging and valuable anecdotal feedback from the study, little useful scientific data was gathered and few people followed through with the instructions and returned the data sheets. However, as was hoped for through implementation of the pilot project, important lessons were learned about working with the local gardening community on this kind of study: the need for ongoing engagement with study participants; the need to design a simpler scientific protocol that was easier to follow; and the need to redesign a simpler data sheet.

VI) 2013 Citizen Science Project

In August 2012 the Sonoma Biochar Initiative applied for a $15,000 grant from the Mental Insight Foundation to expand its Citizen Science project in 2013, using the lessons learned from the earlier pilot study. The application was accepted and the grant was awarded in January 2013.

Rebecca Lawton, a scientist with the Sonoma Ecology Center, was retained to design a new scientific methodology for the project, to redesign the data sheet, and to analyze the data collected. After careful consideration, photo monitoring was chosen as a scientifically relevant, yet simple tool that the general public could use to measure plant growth between plots grown with and without biochar. Since most people have access to digital cameras and email, taking photographs of the plots at monthly intervals and submitting them online was deemed the methodology that most people could use to stay engaged with the study. For those so inclined, a simplified data sheet was also included on which they could record specific additional data including observations regarding water footprint and biomass weight differences (See Appendix item B). This data sheet, if completed, was to be returned to us at the end of the season. All of the biochar/compost bags were made available to participants at no cost.

Photo III Supersacks of biochar from Phoenix Energy

In early April 2013, SBI purchased 1,000 lbs of biochar from Phoenix Energy's gasification facility in Merced, California. Enough compost was donated by Sonoma Compost Company to make a 50/50 mix. Sonoma Compost blended the material and delivered the new mixture to SEC's Sonoma Garden Park on 7th Street East near the City of Sonoma, where it was covered with tarps to keep it dry. With help from volunteers from the Sonoma Garden Park, Green Valley Village, Sonoma State University and SBI's Board, sandbags were filled with the mixture and labeled with brief instructions.

Photo IV Volunteers fill the bags of biochar and compost

Don Osborne, an Environmental Studies student at Sonoma State University doing an internship with SBI, built an ingenious funnel device that made filling the bags much easier. This allowed us to complete filling of 200 bags in about 4 hours. Another 50 bags were filled the following week, making a total potential sample size of 250 bags. Five gallon plastic buckets were used to measure the material.

Through collaborations with organizations such as Daily Acts, the Sonoma Garden Park, IGrow, the Community Garden Network of Sonoma County, the Sonoma Ecology Center, and others, SBI expanded its outreach for the project in April and May. Announcements were posted in newsletters, on SBI's website and those of other organizations, and in local newspapers. Several emails announcing the project were sent out to SBI's own extensive mailing list using the database manager Constant Contact, and a web interface was set up allowing people to register as project participants. Constant Contact was also used periodically throughout the project to remind participants of photo submission deadlines and to keep them engaged with the project.

In addition, SBI

- purchased a booth at the Sonoma Earth Day event where 24 bags were distributed
- purchased a booth at the Marin Earth Day event where 21 bags were distributed
- staffed a table at a Sonoma Garden Park event where 18 bags were distributed

Sonoma Earth Day 2013


Earth Day Marin 2013

By June, 233 bags of the biochar/compost blend were distributed to 183 participants from Sonoma County as well as Marin, San Francisco, and Alameda counties. Some people and organizations requested additional bags to expand their plot size or use it in different sections of their home or facility. The largest number of bags, 16, went to Len Greenwood's Sustainability program at Montgomery High School in Santa Rosa for use on school property.

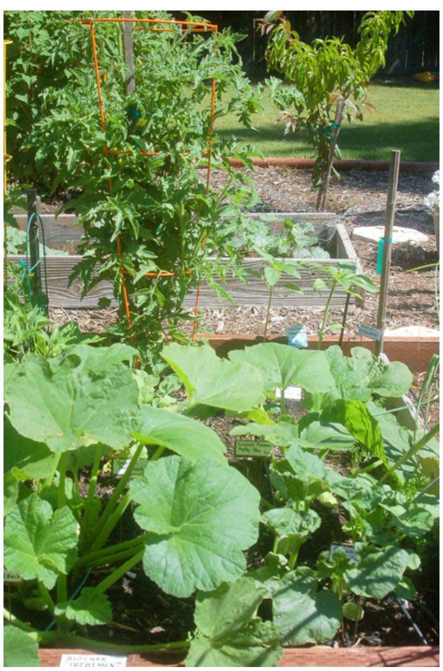
Participants were sent reminder emails at regular intervals throughout the study period through the Constant Contact interface. The emails contained explicit instructions about when to take, label and submit the photos, and provided sample images that had already been submitted to show people some early results. As is typical, not everyone opened their emails: 51% opened the

May 31 email; 45% opened the June 30 email; 44% opened the August 23 email, and 48% opened the September 30 email. In addition, 49% opened an email sent out on January 13, 2014 giving a link to an online survey designed primarily to solicit information from those who took a free bag of biochar/compost mix but did not contribute any data whatsoever. The results of this survey will be discussed later in the report, and the complete survey can be found in Appendix III.

Below are samples of the differences in growth experienced by four study participants in the May-June period. A variety of plants were used in the experiment, including summer squash, tomatoes, bell peppers, padrone peppers, potatoes, lemon cucumbers, Swiss chard, Zinnias, and lettuce.

Treatment Plot

Control Plot



Treatment Plot

Control Plot

Treatment Plot **Control Plot**

Below are charts showing crop success comparisons from each or the three reporting periods. In Charts III, V, and VII the X-axis identifies individual participants by number and the Y-axis shows the percentage of change from the first set of photos submitted in May.

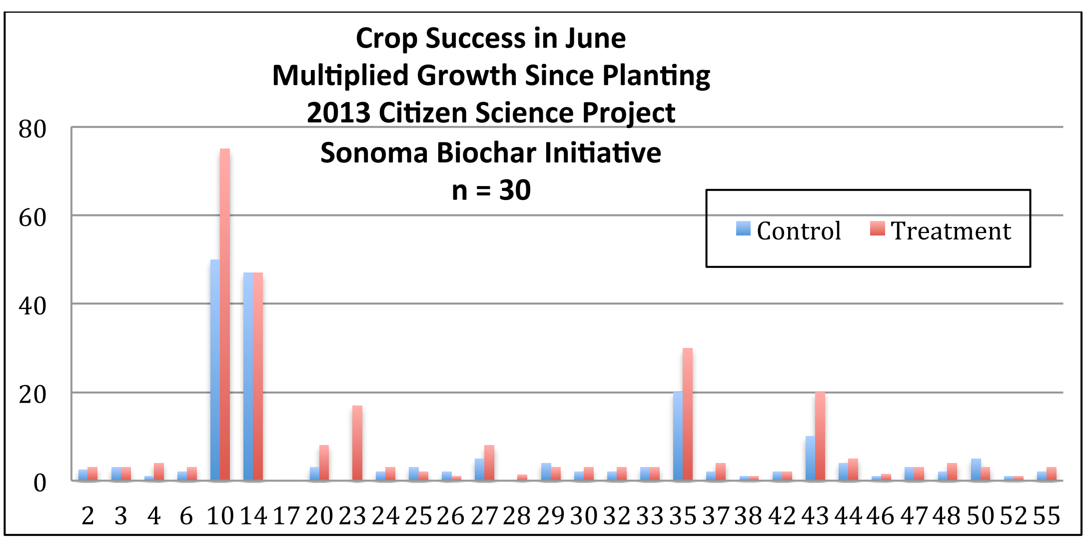


Chart III

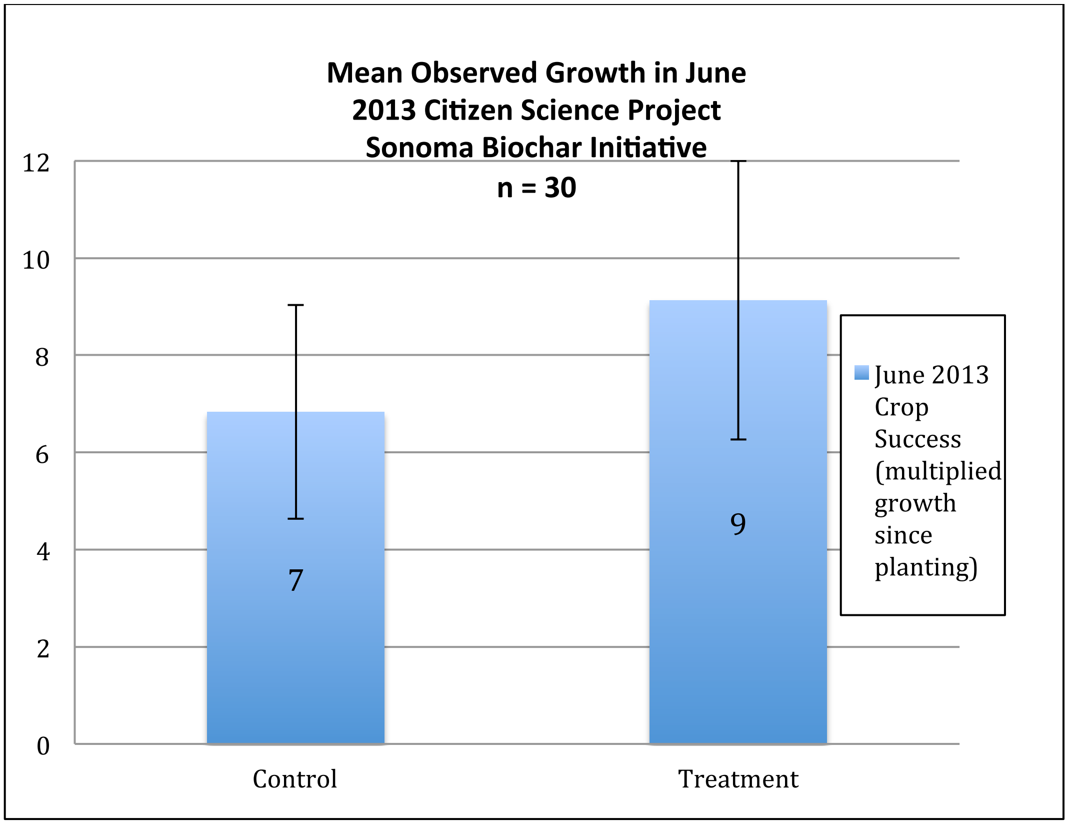


Chart IV

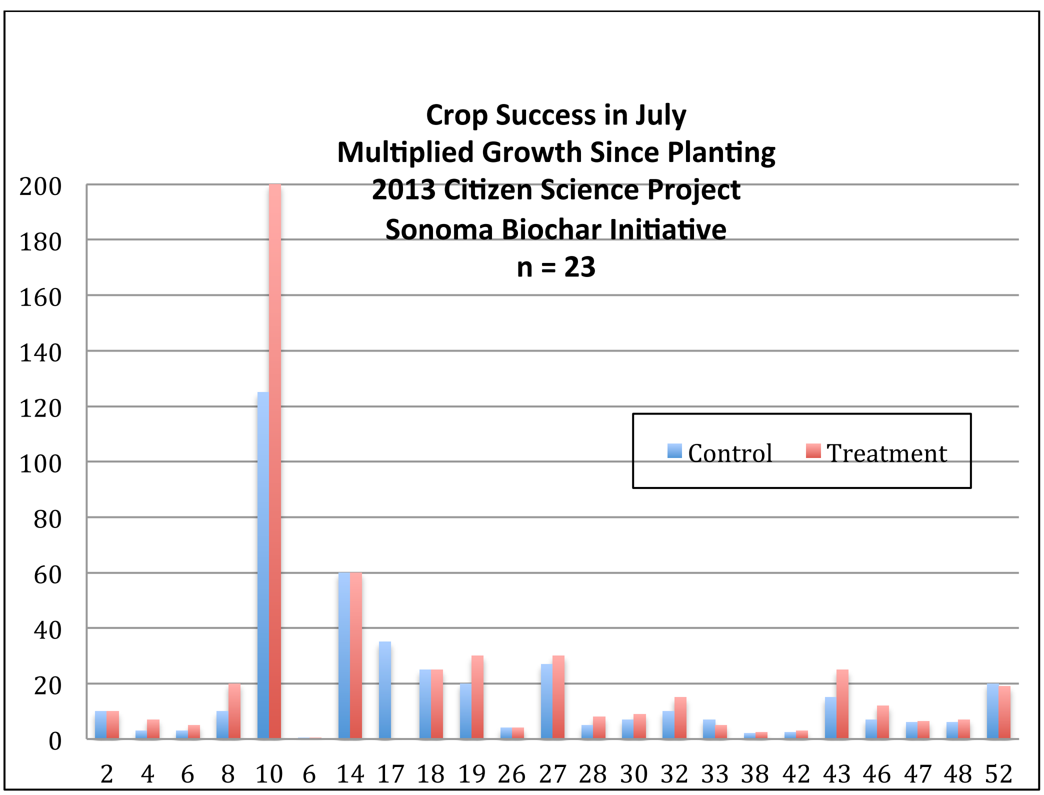


Chart V

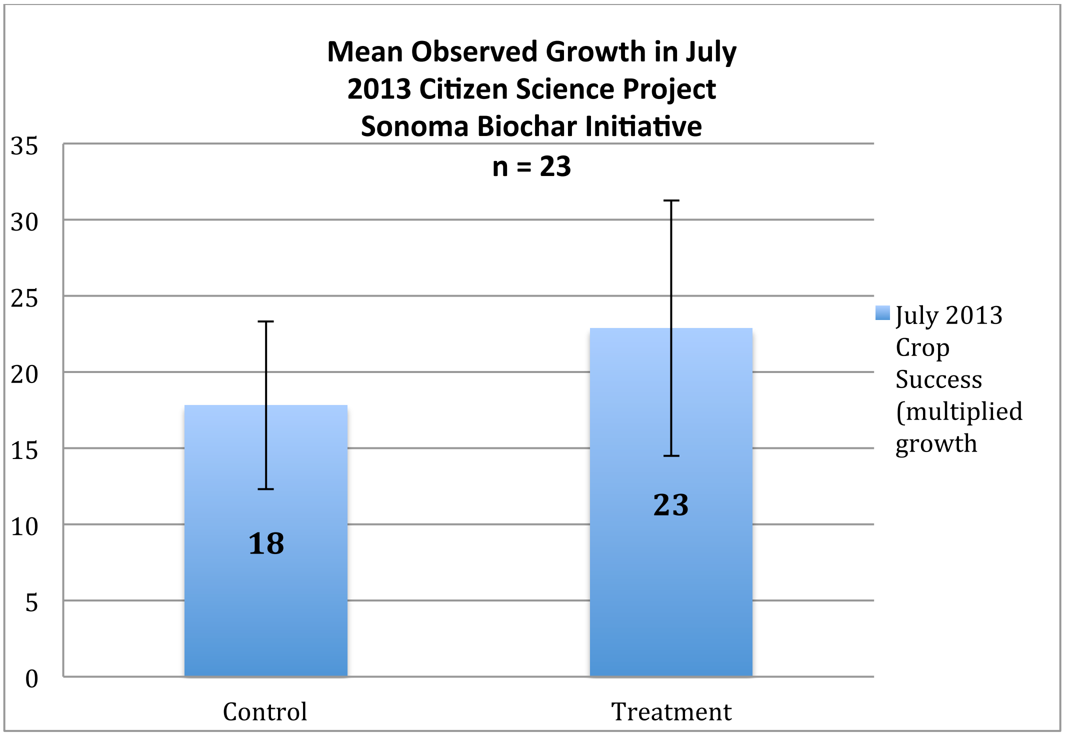


Chart VI

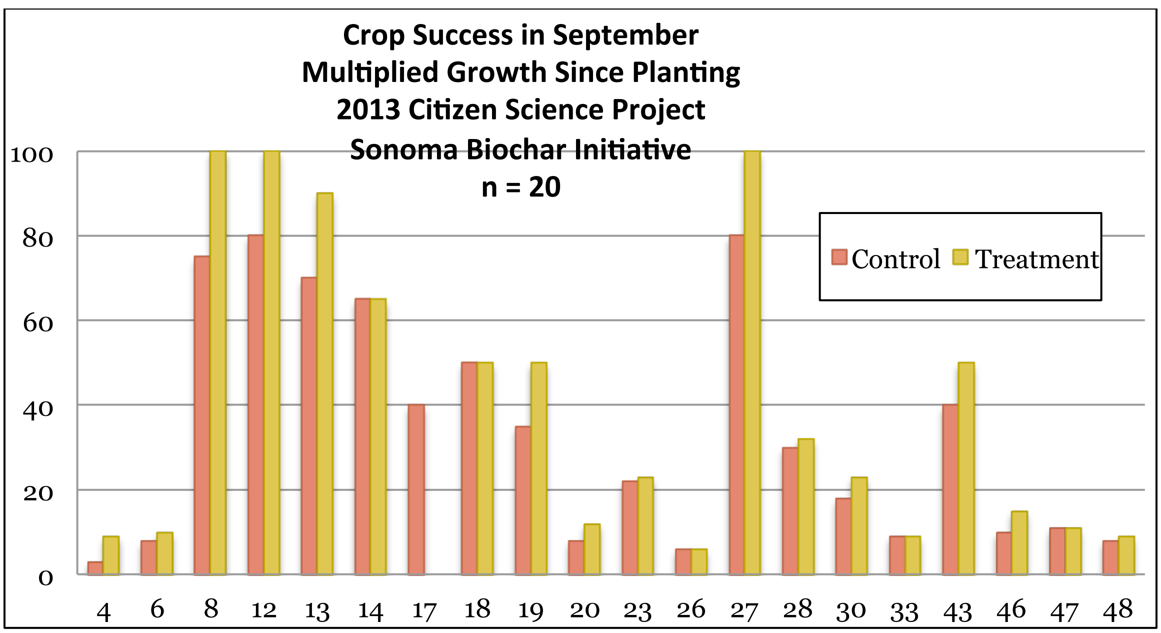


Chart VII

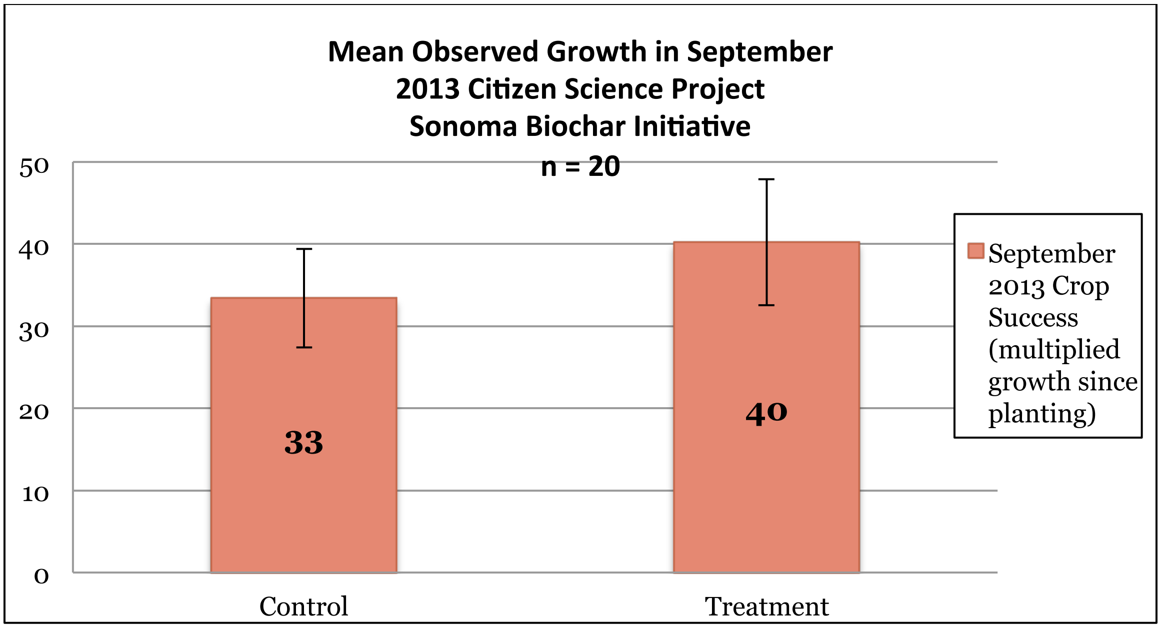


Chart IX

Notes on Crop Success Charts and Data Sheets

1. ***Different scales were used for June, July, and September charts to accommodate range of growth rates.***

2. ***Crop success reports dwindled over course of study, some because of gopher damage, snail damage, and harvesting.***

3. ***I.D. numbers on x axis correspond to unique individuals and remain the same throughout study.***

4. ***Data sheets add to information on watering times, fruit and flower comparison between Control and Treatment plots, and anecdotal information.***

5. ***Majority of notes described success of biochar in garden.***

An increasing number of mainstream organizations and scientists are studying, or even recommending, the use of biochar as way to improve poor or degraded soils. The United Nations Convention to Combat Desertification, for example, supports biochar as a means for combatting land degradation, especially on poor or degraded farmland, and combatting climate change.[6] Though we instructed project participants to use a location in their garden area with the poorest soil to test biochar's effectiveness in this regard, each participants' choice for the test plots may have been arbitrary and quite subjective. No

[6] C.J.Barrow. "Biochar: Potential for countering land degradation and improving agriculture." Applied Geography 34 (2012).

specific soil tests were required nor conducted to our knowledge, however such a study may form the basis of another citizen science project in future years.

Much more research in these areas is currently being done worldwide, adding to a growing body of some 1400 + scientific papers published to date on various aspects of biochar use, production, and effectiveness.[7] We are only now beginning to appreciate the fact that no two biochars are exactly alike, and that those made at different temperatures from different feedstocks may react very differently in a given soil type.

Locally, SBI has spearheaded the Sonoma County Biochar Project. The Sonoma Ecology Center was awarded a USDA Conservation Innovation grant in November 2012 to purchase a biochar production unit called an Adam-Retort. This farm-scale unit will be placed at Swallow Valley Farm in western Sonoma County, and the biochar produced will be used in just such experimental field trials onsite at this farm as well as two other local farms: Green String Farm in Petaluma and Oak Hill Farm in Sonoma.

VII) The Big Biochar Experiment in the UK

As mentioned in the Executive Summary, the genesis of SBI's Biochar Citizen Science projects in 2012 and 2013 was The Big Biochar Experiment, a similar citizen science effort conducted in 2012 by Dr. Cecile Girardin and Dr. Russell Layberry of Oxford University, and Dr. Dan Bebber of the Earthwatch Institute.

The goals of the UK project were:

To conduct a large-scale experiment on the use of biochar in allotments (community gardens) and home gardens, aiming to:

- gather quantitative data on productivity, and qualitative data on plant and soil health of widely used fruit and vegetable varieties
- combine these data with existing information on weather and soil quality, to understand the effects of biochar on the productivity of plants across a range of soils

A web site was created and those that were interested in participating signed up online. Bags of (unconditioned) biochar were then shipped to participants along with data sheets to fill out and instructions. The experiment was publicized through blogs, newsletters, magazine articles, twitter, word-of-mouth, etc. The methodology used was similar to ours: participants were instructed to make two 1-meter square plots and to use biochar in one and not in the other; to plant in each plot and measure and record the results and return them. They were most concerned with both above ground and below ground weight measurements at harvest, but asked a number of other questions including plant type, whether compost or fertilizer was added, date of sowing and harvesting,

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[7] International Biochar Initiative. Bibliography. 10 February 2014 <http://www.biochar-international.org/biblio>.

etc. Below is a summary gleaned from a video of Dr. Girardin presenting some preliminary information about the experiment[8]:

- 344 bags of biochar were sent out around the UK
- 73 participants reported that they had carried out the experiment
- 44 participants actually sent in data, of which 38 were considered useable
- Despite the small number, the results obtained were robust -- participants were rigorous in their documentation
- Impressive growth results were received on beets, radishes, and some other varieties but some "not so good results" were also received
- Overall there was a 15% increase in the weight of the plants in the biochar plots over the control plots
- The researchers are planning on continuing the experiment using an improved methodology, re-phrasing some questions and coming up with a strategy to better motivate citizen scientists to send in their data

VIII) Citizen Science Post Study Survey

To get a better understanding of our participants' experience with the project, along with the reasons why people took bags of biochar but did not submit any photos or data—an online survey was conducted between January 12 and January 20, 2014. This survey was sent to all participants who took bags of biochar, however we specifically encouraged those who did not submit data to respond. We publicized that the responses would not be directly correlated to individuals—in other words they were anonymous. A total of 46 people responded, and 36 indicated that they had used the biochar/compost material in their garden but had not submitted data to us.

The complete survey results are attached to this report. Here is a summary of the results:

- 23 men and 23 women took the survey.
- 78% lived in Sonoma County; 11% in Marin, 7% in San Francisco, & 4% in Alameda
- 70% were 50 and older, 24% were between 30 and 49, and 6% were under 30.
- 90% had a home garden, 6% a plot in a community garden, and 4% a school garden
- 96% found the planting and use instructions clear and understandable, 4% did not
- 71% found the data sheet instructions clear and understandable; 18% found them clear and understandable but thought it would take too much time to fill out; 2% thought they were not clear and understandable, and 9% were unsure

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[8] Girardin, Cecile Dr. Cecile Girardin – "The Big Biochar Experiment". 26 January 2014 <http://www.youtube.com/watch?v=pNM4CNiSeKE>.

- 95% said they used the bag of biochar and compost in their garden, 5% did not
- 93% experimented with vegetables, 17% with flowers, 10% with fruit, and 17% with herbs

Four questions we posed in this follow-up survey were of most interest to us; results are given below along with some comments that were offered:

Q7) What was the most challenging part of the project for you?

Answer Options	Response Percent	Response Count
Finding the time to devote to it	23.8%	10
Taking the photos and/or uploading them	21.4%	9
The gophers/insects/bugs ate my plants	9.5%	4
Following the directions for planting	4.8%	2
Filling out the data sheet	21.4%	9
I didn't find the project challenging at all	19.0%	8
Other (please specify)		9
	answered question	42
	skipped question	4

Comments:

1) I worked with folks at a community garden who didn't have the time to take photos or update a data sheet . Difficult to get side-by-side plots with identical plantings.
2) I was away and missed the critical photo dates The plants I chose were not the best for measuring the yield of. The broccoli went to seed quickly, the kale got powdery mildew and I removed it and the tomatoes grew so vigorously they hid the potatoes. Maybe carrots, beets and potatoes next time.
3) Gophers killed all the plants
4) Not taking the photos but uploading them. My camera quite working and I could not afford another one. I took photos from my ipod but I took photos from my ipod but could not take the time from work to learn how to download
5) Our baby came 2 weeks early and sabotaged all of my gardening plans for 2013!
6) Separately irrigating the test plot and the control plot
7) Living abroad at the moment

These results gave us a good idea about areas of improvement if and when we conduct another study. The largest percentage, 24%, found it hard to find (or make) the time to devote to it, and another significant number of participants had trouble with technical issues such as taking or uploading the photos or filling out the data sheet (21% and 21% respectively). Another 19% indicated that they had no challenges with the study at all.

Q10) If you used the biochar/compost mix in your garden but just didn't get around to taking photos, which best describes your general observation of the plants grown in this area?

Answer Options	Response Percent	Response Count
They grew bigger and/or healthier than similar plants elsewhere in the garden	58.3%	21
I couldn't tell any difference	33.3%	12
They grew smaller and/or less healthy than similar plants elsewhere in the garden	0.0%	0
I don't know	8.3%	3
	answered question	36
	skipped question	10

Comments:

1) I planted the same tomatoes in the biochar bed and the bed without the biochar. The ones in the biochar bed were 3 times bigger and produced 4 times the amount of fruit.
2) I had 3 plots one with just my regular compost - 1 with the compost and biochar and one was just a plot on ground – weedy ugly dirt - no compost - with added biochar. THAT was the one that did the best. Second best was the NO biochar plot, worst was the compost and Biochar plot.
3) The reason I did not send in photos was because I live on a sheep ranch and the sheep broke into the garden unfortunately. Therefore the experiment was not able to be completed.
4) Gophers ate all the plants
5) It wasn't the size of the vegetables as much as the quantity produced.
6) Actually, the control group grew almost as healthy and big, but took longer to do it. The biochar group grew faster. Since the biochar was reportedly activated with fertilizer
   I'm not surprised –-the other side had no fertilizer at all.
7) The biochar side looked more robust initially, but at the end of the season, plot growth appeared to be the same in biochar and control plots.
8) Unfortunately, deer got to the biochar tomato plant early on and squash bugs got to the giant pumpkins. The pumpkins didn't survive. The tomato plants ended up about the same size in the long run.
9) They dealt with drought better too. If I didn't get around to watering regularly, the control plants wilted but the biochar plants still looked good.

As with those who sent us data during the study, a majority of participants in the survey showed improved crop success in the treatment plot over the control. While unverifiable, these results are consistent with those obtained from photomonitoring.

Q11) If you didn't contribute photos or observations to the study, which of the following best describes why?[9]

Answer Options	Response Percent	Response Count
Not Applicable	27.3%	3
I just never got around to planting this year	0.0%	0
The plants died	0.0%	0
The plants got eaten by gophers/insects/bugs	9.1%	1
I meant to, but just never found the time to document the plot	9.1%	1
My camera or computer died	9.1%	1
I moved	0.0%	0
Other (Please explain below)	45.5%	5
Please add any comments you might have		8
	answered question	11
	skipped question	35

Comments:

1. The community garden had to move
2. I was on vacation & missed the critical dates
3. lost camera
4. I submitted photos but neglected to take the time to fill out the data sheet because I didn't do a good job of regular documentation of watering schedule etc. overall I thought the biochar plants were bigger than the control plot.

Q13 Please give us any additional feedback you have about the 2013 Citizen Science Project.

Comments:

1) I put biochar in many parts of my garden and, with exception of my basil plants, every it was used we had better production from our vegetables. This next year I plan to expand the use to several flower beds.
2) It was a worthwhile experiment with clear results. And I would really like to purchase more Biochar.
3) I think it was really cool! I like the idea of offering a manageable science project to every-day gardeners.
4) It was awesome!
5) I will do the same project again in the 2 beds to see if the biochar makes a difference in the second year. I may add more biochar.
6) I appreciated being a part if it but felt bad I didn't fulfill my end of the bargain by submitting the final piece/data sheet.
7) Easy to do. We would like to continue to use biochar to enhance our garden.

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[9] *Note: We added Q11 after 30 people had already taken the Survey, so this is why there was such a low response count.*

8) I loved the experiment and the product. Biochar appeared to make a significant difference in the size and health of the plants so now I'm using it in the entire bed for a winter crop and next season.
9) It was an excellent project. Thanks for doing it!
10) I would use biochar every year if it were readily available.
11) I got 4 bags of biochar from Sonoma Compost and plan to use it in my garden this summer.
12) The water usage for my veg.garden was minimal and the biochar treated plants did much better. I last about 40% of the non treated plants.
13) The small plot that was created for this project did show noticeable differences in plant size and quantity produced in the 2012 growing season. Happy with the results especially with the observed assistance in water retention.
14) Biochar sounds cool, but the wood could just be composted for similar effect. Takes longer of course, and some woods won't work -- must be burned instead.
15) Thank you for your coordination efforts. I appreciate it.
16) I began with uploading photos and then realized that I was watering incorrectly and thought my data would mess the results up from others who did the experiment correct. So I did not submit any data sheets or photos.
17) Thank you for doing this!
18) the soil in my plots is generally excellent, and the biochar plot did not look any different from the control plot. to do the experiment, as it was designed, was to observe the difference in the amount of irrigation required. I found this extremely hard to observe, because In my garden both plots got approximately the same amount of water, and both plots looked similar throughout the season.
19) It was a great opportunity to see first-hand the benefits of biochar.
20) how about the drought??
21) It was an excellent experiment which I thoroughly enjoyed and learned from; if repeated in 2014, I would sign up.
22) The control and experimental plot areas were rather small and therefore you could not have very many plants in either plot. By the time the bugs/insects got their share there was only one viable plant in each plot.
23) Thank you for the opportunity!
24) Might be easier for you to ask people to put yardstick in the photos. I appreciated the chance to participate.
25) I will use biochar in the future. I'm sorry I couldn't provide more information.
26) I had a medical issue from July through November that took up a lot of my time, so I didn't submit my final photos and feedback. My apologies.

IX) Lessons Learned

- Photo monitoring is a successful tool for measuring garden growth and comparing growth between test and control plots.
- Few citizen scientists followed instructions to submit data, from properly labeling and attaching photos to responding at all, adding to the challenge of photo comparisons. Simplifying the data sheet, or adding an online form to submit this data and written observations during the study, might increase participation.
- Subjectivity was introduced by researchers analyzing submitted photographs. Participants who also submitted anecdotal evidence in data forms added greatly to confidence in the photo analysis.
- There was a wide variance in the quality and angles of the submitted photos, which made analysis somewhat challenging
- Additional data can be analyzed from paper copies, original emails, watering time analyses, and notes in Excel spreadsheet. There were not enough funds to do a complete analysis of all the data collected. Additional analysis could be done regarding which individuals responded every month and why, and fruit and flowering during study (visible in some photos).
- An additional step of discussing results with participants as soon as practicable after the final month of observation would likely result in higher success rates in interpretation of photographs and field notes.
- More precise results may be obtained if plant types were limited to one or two varieties only, and/or specific plant types (such as Early Girl Tomatoes or a specific type of heirloom broccoli or tomato) were required. It is possible, then, that different soil types and microclimates may play a more significant role in productivity and these factors would be easier to identify.
- No data was requested regarding use of organic gardening methods vs use of chemical fertilizers. This could be a significant variable to track in future studies.

X) Acknowledgements

We would like to thank a number of people and organizations for their assistance in making this citizen science project a success:

The **Mental Insight Foundation**, for funding this project.

Scientist Rebecca Lawton, for her project design, ongoing guidance, photo analysis, data analysis, and Excel charts. Rebecca is a fluvial geologist whose work in citizen science includes serving on the Technical Advisory Committee for the California Water Resources Control Board Clean Water Team as well as designing and founding the Sonoma Ecology Center's volunteer-assisted stream monitoring program, which she managed for over a decade. She has conducted peer-reviewed research for the U.S. National Park Service and U.S. Forest Service, led sediment-related sampling and monitoring for the multi-partner Sonoma Creek Total Maximum Daily Load sediment source analysis, and conducted restoration site prioritization studies related to fine sediment supply. Her website is www.beccalawton.com.

SBI Board members Ray Gallian and David Morell, SBI intern Don Osborne, Anke Hegemann from Green Valley Village, and the interns at the Sonoma Garden Park, for their help filling and distributing the bags of biochar and compost.

SBI interns Don Osborne and Autumn McElroy for their help with categorizing, cataloguing and analyzing the photos, as well as bagging and distributing the biochar.

Sonoma Compost for their kind compost donation.

Phoenix Energy for producing the biochar.

Our wonderful organizational collaborators: Daily Acts, IGrow, The Share Exchange, the Sonoma Garden Park, the Community Garden Network of Sonoma County, and all the citizen scientists who took time out of their busy lives to try something new.

Raymond Baltar, Principal Investigator and lead author of this report. Raymond is the Director of the Sonoma Biochar Initiative and served as Chair of the 2012 USBI National Biochar Conference at Sonoma State University. He became interested in biochar and sustainable agriculture in 2009 while in graduate school studying alternative business models and practices at Dominican University of California. He holds an MBA in Sustainable Enterprise from Dominican, has written business plans for several biochar-related ventures, and works as a biochar consultant, educator, and project manager. SBI's website is: www.sonomabiocharinitiative.org and Raymond's email is: rbaltar@sonic.net.

XI) APPENDIX

A. 2013 Citizen Science Project Instructions

<u>Primary goal</u>: To investigate the impact of biochar on crop success. Your participation in experimental plot data collection is essential!

<u>How you can help</u>: Set up comparative plots, tend your plants, and collect data to contribute to the study results.

<u>How to get started</u>: Read this sheet for instructions on how to use and evaluate the impact of Biochar during this growing season.

Step One: Create Your Plots

The purpose of this experiment is to assess the comparative health of plants grown with and without Biochar. To do so, you will set up identical growing plots, side by side. Everything about the plots must be the same, except one plot will have Biochar added and one will not. It is best to locate the test plots as close to each other as possible, so they'll receive similar amounts of sunlight and rain.

The standard garden plot in this study is 3 feet wide by 3 feet long. Establish two plots, one marked **Control Plot** (without Biochar) and one marked **Treatment Plot** (with Biochar). If your plots are smaller or larger than the standard, you can still participate. You'll just vary the amount of Biochar you apply, as noted in Step Two.

Fill your plots with poor quality or unfertilized soil, the worst in your garden, if possible. Results will likely be more marked if you start with ordinary soil instead of soil that has already been improved. This study is not looking for which participants get the best results; rather, this study aims to know how results differ between your two plots. Any treatments and soil amendments, except the application of Biochar and amount of water applied after planting, must be identical for the two plots. Biochar may be applied to second- or third-year plots. Changes build in soil over time.

Step Two: Add the Biochar and Plant Your Crops

Prepare your **Treatment Plot.** To do so, mix the contents of the **Compost/Biochar** bag into the soil to about 6 inches deep. (Note that one bag will cover a 3-foot by 3-foot plot to 6 inches deep, but if you are using smaller plots, you can scale back the amount of **Compost/Biochar** accordingly to achieve this same depth of application.)

Next, prepare your **Control Plot.** To do so, treat the plot with whatever material you normally use to amend your garden soil. If you generally use compost, spread it evenly across the surface and mix it into the soil about 3 inches deep. The amount you apply should be half the amount of **Compost/Biochar** applied to the **Treatment Plot.** A simple method of measurement is to fill the empty **Compost/Biochar** bag halfway with your own material. Instructions for Biochar application can also be found on the packet.

After preparing the soil, begin planting. Remember to maintain these same characteristics for both plots:

● Type of seeds planted ● Pattern and spacing of the seeds within the plots ● Date of planting ● If applying Biochar to already-established plants, it must be applied to the root zone of identical species of similarly aged plants in each plot.

Step Three: Collect Data and Photos

Once you have set up your plots and planted, please fill in Page 1 of the **Datasheet**. You'll need only one 2-page **Datasheet** for both plots for the entire season, which will include instructions on data collection and plot management. Carefully record any application of fertilizer or compost made to the plots before or during planting. The **Datasheet** will prompt you for this information.

Once planting is complete, take a photo of the two plots and note the information called for on the datasheet. Always photograph from the same compass point for each plot. Include an unmovable object in the photo (e.g., pole in the background, wooden railings in the foreground) to help relocate your photopoint for the "After" photographs you'll take later in the season. Complete all sections of Page 1 of your datasheets. Keep your **datasheet** in a safe place so it will be available throughout the study.

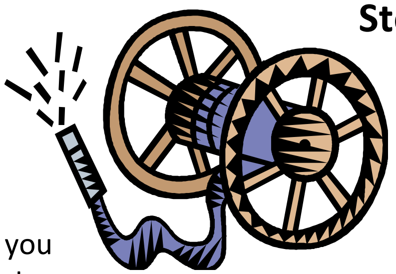
Maintain a photomonitoring schedule as close to the following as possible:

- May 1st: Planting and PhotoSet0
- June 1st: First month observations and PhotoSet1
- July 1st: Second month observations and PhotoSet2
- September 1: Fourth month observations and PhotoSet3.

Save your first photos as jpegs named for the plots they represent: YearMonthDay_YourName_ControlPhoto0 (e.g., 20130401_JoeBloe_ControlPhoto0 and 20130401_JoeBloe_TreatmentPhoto0). Email two photos only per email to research@sonomaecologycenter.org with "Citizen Science" in the subject line.

After 1 month, 2 months, and 4 months, you will email identically framed photos of your plots to the same e-address.

Follow-up photo files must be jpegs named YearMonthDay_YourName_ControlPlot1 (or TreatmentPlot1), YearMonthDay_YourName_ControlPlot2 (or Treatment Plot 2), and YearMonthDay_YourName_ControlPlot4 (or TreatmentPlot4). You will email only eight photographs in the course of the monitoring. Instructions for mailing hard copy rather than emailing are in Step Seven, below.



Step Four: Water Your Crops as Needed

Up until now, you have treated each plot the same, other than your application of Biochar to the treatment plot. Continue these identical treatments, with one important exception: when you are watering your plants, you must treat your plots differently. Please respond to them according to their water needs and moisture in the soil rather than watering both plots exactly the same amount every time. You should also record the different amounts of water you apply to each plot to maintain proper soil moisture. Fill in Page 2 of your datasheet with your observations about watering. It will prompt you for the correct information.

Step Five: Harvest Your Crops

When your plants reach full growth in each plot, harvest them. This may mean that you harvest on different days for each plot depending on crop readiness. However, you will need to harvest all your plants from one species at the same time within each plot (e.g., all your carrots from the control plot will be harvested simultaneously). Make sure to make a note of your harvest date on Page 2 of your datasheet. Harvest time is also the time to take your final photos of the plots before plant removal. Read the datasheet for instructions on how to complete data collection.

Step Six: (Optional) Measure Your Harvest

(Step Six is intended for those citizen scientists who want to go to the next level of data collection and analysis!)

Each time you harvest one or more plants from one of your plots, please enter the following data on Page 2 of your datasheet.

- Date of harvest
- Plant species
- Aboveground and belowground weights – divide your harvested plants into the mass visible above the soil surface and that below. Weigh the aboveground and belowground portions separately using a standard kitchen scale and record the results in ounces or grams, whichever your scale records
- Area harvested – List this information whether you are fully clearing out your plot or harvesting a portion of the area
- Note any observations you make during the growth and harvesting process. You may include comparisons between plots, conditions that are different compared to other years, or anything else you observe about the results of your experiment. The datasheet will guide you in recording your observations.

Step Seven: Send in Your Results!

Once your plants have been harvested and all data is collected, please complete your datasheet and email to **research@sonomaecologycenter.org.** Or if you prefer to mail in printed results, print your photos and datasheets, gather in one envelope, and return to the following address. Keep copies for your own files! **Research Director,** Sonoma Ecology Center, P.O. Box 1486, Eldridge, CA 95431. Please write “Citizen Science Project” on the outside of the envelope and include your email address with your materials if you’d like us to send study results!

B. 2013 CITIZEN SCIENCE DATA SHEET PAGE 1

CROP SUCCESS

What is it?	**Crop success** is positive plant progress according to several indicators. Factors to be evaluated include increased biomass, acceptable seedling growth, good leaf color, healthy plant vigor, limited pest/disease activity, and good crop taste.
What changes it?	Environmental factors such as soil quality, water quantity, seed variability, and sunlight availability. Application of biochar will potentially improve some factors.
Why measure it?	Observing changes in crop success with varying applications of biochar will yield information about the value of biochar as a soil amendment.

Photomonitoring

To assess the effects of biochar, all factors are kept constant among plots being evaluated--except for the quantity of biochar applied. For biochar assessment, evaluating crop success is done comparatively, observing the varying progress of crops in different plots. Photomonitoring is the simplest US EPA-approved method of demonstrating plant success.
Equipment needed: Measuring tape, this sheet, clipboard, pencil, clock, camera, and email or mail access.

Instructions

Step 1. Sketch planting plan for each 3' by 3' plot. Note plot contents (common names of plants installed) below, as well as time and date of planting.
Step 2. Plant plot as sketched and amend as instructed with compost and biochar.
Step 3. Photograph plot from identical compass point on both plots. (Ensure permanent landmarks are in photo to help locate follow-up photographs.) Mark X for location of camera points next to boxes, below.

	PLOT 1: Compost Only		PLOT 2: Compost + Biochar	
Plot contents: Planted: Date ______ First photograph: Date/Time ______				Plot contents: Planted: Date ______ First photograph: Date/Time ______

Step 4. Email photo jpgs, one for each plot during four separate photography rounds, to research@sonomaecologycenter.org. File name must be in this format: YearMonthDay_YourName_ControlPlot0 (or TreatmentPlot0). Example: 20130401_JoeBloe_ControlPlot0. After 1 month, 2 months, and 4 months, you will email identically photographed photos of your plots to the same e-address. Follow-up photo files must be jpgs also and named in this format: YearMonthDay_YourName_TreatmentPlot# (or ControlPlot#) for 1 month, 2 months, and 4 months (final photo). Each participant will email a total of eight photographs in the course of the monitoring. Or, if working with hard copy, print photos, mark them, and mail along with scanned and completed datasheets to Research Director, SEC, P.O. Box 1486, Eldridge, CA 95431. See instructions for more details or go to sonomabiocharinitiative.org/citscience.

2013 CITIZEN SCIENCE DATA SHEET PAGE 2

WATER FOOTPRINT

What is it?	**Water footprint** is a measure of water use based on watering time required to prevent wilting and death of plants within a growing plot.
What changes it?	Watering time, water pressure, type of application device, evapotranspiration rates, and crop type. For biochar assessment, all factors are kept constant except for quantity of water applied as measured in time and frequency of watering.
Why measure it?	Comparing a plot's water footprint with that of an untreated or differently treated plot will yield information on the water-retention value of a biochar application (given equal water-application techniques among plots)**. Equipment needed to assess: Watering can or hose, this sheet, clipboard, pencil, clock, and email or mail access.**

Watering Frequency

Control Plot How often do you water? Daily? Y __ Every other day? Y __ Other: Y __ specify: _____________	**Treatment Plot** How often do you water? Daily? Y __ Every other day? Y __ Other: Y __ specify: _____________

Watering Time Required

Keeping the watering method (e.g., hose, sprinkler, can) consistent between plots, how long do you water each time?

Control Plot How long do you water? 10 minutes? Y __ 20 minutes? Y __ Other: Y __ specify: _____________	**Treatment Plot** How long do you water? 10 minutes? Y __ 20 minutes? Y __ Other: Y __ specify: _____________

HARVEST NOTES

Date of Harvest/Area Harvested	**Plant Species Harvested**	**Notes (issues, comments)**
Control Plot :		
Control Plot :		
Treatment Plot :		
Treatment Plot :		

OPTIONAL: PLANT WEIGHT

What is it?	**Plant weight** is a measure of biomass grown within a plot.
What changes it?	Soil quality, seed quality, treatments and amendments, sunlight, pests and disease, water availability, and other environmental factors.
Why measure it?	Keeping the above factors constant between plots with the exception of biochar and biochar-dependent watering variations gives us information about the impact of biochar on plant growth. **Equipment needed to assess: Kitchen scale, this sheet, pencil.**

Date of Harvest/Species Harvested	**Stem Wt (oz or grams)**	**Leaf Wt (oz or grams)**	**Belowground Wt (oz or grams)**	**Notes (issues, comments)**
Control Plot :				
Control Plot :				
Treatment Plot :				
Treatment Plot :				

C. POST-PROJECT SURVEY

See Attached PDF

XII) Works Cited

Barrow, C.J. "Biochar: Potential for countering land degradation and improving agriculture." Applied Geography 34 (2012).

Girardin, Cecile Dr. Cecile Girardin - The Big Biochar Experiment. 26 January 2014 <http://www.youtube.com/watch?v=pNM4CNiSeKE>.

Girardin, Dr. Cecile, et al, 2013. Tropical Ecologist, Oxford University. Private interview with Raymond Baltar. 23 January 2014.

Hardy Schulz, Gerard Dunst, & Bruno Glaser. "Positive effects of composted biochar on plant growth and soil fertility." Agronomy for Sustainable Development 33.4 (2013): 817-827.

International Biochar Initiative. Bibliography. 10 February 2014 <http://www.biochar-international.org/biblio>.

International Biochar Initiative. What is Biochar. 30 January 2014 <http://www.biochar-international.org/biochar>.

Lehmann, Dr. Johannes. USBI Biochar Conference. Amherst, Mass. 14 October 2012.

Woolf, Dominic. "Biochar as a soil amendment: A review of the environmental implications." January 2008.

Report published February 18th, 2014.