Biochar Research Project Report 2021

Produced By: Citizens for Clean Air, Grand Junction CO

www.citizensforcleanair.org, 970-242-1054, citizensforcleanair@gmail.com

PO Box 101, Grand Junction, CO 81507

November 10, 2021, Updated March 8, 2022

Project Summary

Biochar and compost both have the potential to increase crop productivity in the short term and improve resilience by retaining soil moisture and nutrients in the long-term. As an added benefit, biochar also sequesters carbon for long periods of time because biochar is primarily elemental carbon that is not easily converted to CO_2 by soil microorganisms.

The first year's experiment focuses on short term benefits. It took place at two locations, each with four subplots planted with the same vegetables – Ace Bell Peppers, Charger Peppers, Asian Eggplant and Curly-leafed Kale. The four subplots had different soil amendments – compost plus 20% biochar, compost plus 10% biochar, compost-only, and none.

The table below presents summary statistics of the weight of each crop in each subplot and a comparison of the subplots to the control subplot 4. The subplot with the greatest harvest weight relative to subplot 4 is bolded; the amended subplots with values less than subplot 4 are red.

Lobato Farm	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**
Soil Amendment	**20% Biochar/Compost**	**10% Biochar/Compost**	**Compost Only**	**Control – No Soil Amendments**
Ace Bell Pepper				
Total (oz)	71.0	212.1	91.7	37.7
Relative to plot 4 (%)	189.0	**563.0**	244.0	100.0
Charger Chili Pepper				
Total (oz)	194.7	334.3	371.2	122.9
Relative to plot 4 (%)	158.0	272.0	**302.0**	100.0
Asian Eggplant				
Total (oz)	218.8	552.4	193.3	147.2
Relative to plot 4 (%)	149.0	**375.0**	131.0	100.0
Curly-Leafed Kale				
Total (oz)	197.5	195.0	156.8	184.2
Relative to plot 4 (%)	**107.0**	106.0	85.0	100.0
Santa Fe Ranch HOA	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**
Ace Bell Pepper				
Total (oz)	31.7	18.4	33.9	27.9
Relative to plot 4 (%)	114.0	66.0	**122.0**	100.0
Charger Chili Pepper				
Total (oz)	90.3	63.6	51.7	52.7
Relative to plot 4 (%)	**171.0**	121.0	98.0	100.0
Asian Eggplant				
Total (oz)	32.0	63.2	98.9	71.5
Relative to plot 4 (%)	45.0	88.0	**138.0**	100.0
Curly-Leafed Kale				
Total (oz)	48.0	34.0	32.0	24.1
Relative to plot 4 (%)	**199.0**	141.0	133.0	100.0

Summary Statistics- Production Quantity by crop and subplot.

Notes: Plot 1 is compost + 20% biochar, Plot 2 is compost + 10% biochar, Plot 3 is compost only, Plot 4 is no amendment.

In all cases, the harvest weight from at least one of the amended plots, was greater than from subplot 4 (no amendment – the control). Subplot 2, which contained 10 percent biochar, yielded the largest produce weight for two of the four crops at Lobato Farms but none of the sub plots at the Santa Fe HOA. Subplot 1, which contained 20 percent biochar, yielded the greatest harvest weight for kale at Lobato Farms. The mixture of 20 percent biochar for both chili pepper and kale yielded the highest weight at the Santa Fe HOA.

Using estimates of the market value of the crops, it is possible to assess the relative value of adding the different soil amendments (see table below). For both locations, using the amendments generated higher yields and the potential for more revenue. The sub plots containing biochar (1 and 2) also had higher value of output than the compost-only plot 3 at the Lobato Farm. Plot 3 did slightly better overall at Santa Fe than plot 2. The results for individual crops differ somewhat from the overall results. But only in one case (kale at Lobato's) did plot 4 (no amendments) do better than an amended plot (plot 3). These results provide some initial confirmation of the value of using compost with biochar added.

Lobato Farms					
CROP	PLOT 1	PLOT 2	PLOT 3	PLOT 4	SUBTOTAL
Bell Pepper ($)	$ 4.40	$ 13.30	$ 5.70	$ 2.40	$ 25.80
Chili Pepper ($)	$ 12.20	$ 20.90	$ 23.20	$ 7.70	$ 64.00
Eggplant ($)	$ 13.70	$ 34.50	$ 12.10	$ 9.20	$ 69.50
Kale ($)	$ 98.70	$ 97.50	$ 78.40	$ 92.10	$ 366.70
Total Value per Plot ($)	**$ 129.00**	**$ 166.20**	**$ 119.40**	**$ 111.40**	**$ 526.00**
Santa Fe Ranch HOA					
CROP	PLOT 1	PLOT 2	PLOT 3	PLOT 4	SUBTOTAL
Bell Pepper ($)	$ 2.00	$ 1.20	$ 2.10	$ 1.70	$ 7.00
Chili Pepper ($)	$ 5.60	$ 4.00	$ 3.20	$ 3.30	$ 16.10
Eggplant ($)	$ 2.00	$ 4.00	$ 6.20	$ 4.50	$ 16.70
Kale ($)	$ 24.00	$ 17.00	$ 16.00	$ 12.10	$ 69.10
Total Value per Plot ($)	**$ 33.60**	**$ 26.20**	**$ 27.50**	**$ 21.60**	**$ 108.90**

Estimated value of production per crop and subplot USD ($).

Note: Prices used for value calculation reflect wholesale value in September 2021. Kale, $8 per lb. Other crops, $1 per lb.

Overview of project

For some time, Citizens for Clean Air (CCA, https://www.citizensforcleanair.org) members have had an interest in the potential benefits of biochar to reduce air pollution from burning of various sources of biomass and to convert a waste product – with negative impacts on air quality – into a valuable resource for agricultural and other uses.

CCA began planning for the project in January 2021, after having received grant funding the previous December from the Western Colorado Community Foundation – Dave and Mary Wood Fund.

CCA contacted several local horticulture experts as well as consultants from out of state for advice and expertise. Valuable resources for this project include Colorado State University Extension Tri-River Area (Mesa County) and input from the Mesa County Recycling Center.

Because Grand Valley soils have a high variability, CCA hoped to experiment with plots in different areas throughout the valley. We explored local farming and gardening resources to see who might be interested in hosting a study plot starting in the spring of 2021. We used the CCA Newsletter, organized an introduction to biochar for our annual public forum and received media coverage in The Daily Sentinel, local TV stations, and Colorado Public Radio

Our search was rewarded with five interested parties. Unfortunately, one of them, the Cross Orchards Historic Site, would not be ready for a biochar garden plot in time, and the donated Mesa County Fairgrounds garden space was more than we felt we had the resources to handle at that time, leaving us with three donated plots for the study:

- A first-year produce farm on the outskirts of Fruita, Lobato Farms, formerly a sheep ranch, currently owned and operated by Michael and Sara Lobato
- Two raised garden beds owned by the Santa Fe Ranch Homeowners Association in Fruita
- A third-year vegetable farm, Green Junction Farmstead (GJF) in the Clifton/Palisade area, a Community Supported Agriculture service (CSA). GJF became a valued resource; however, because harvesting practices at this location had been long established, we were not able to harvest and weigh the fruit produced at the different plots.

Biochar and Compost Purchase and Handling

We pre-loaded the pore structure of biochar with bacteria, fungus and nutrients from compost. This is best accomplished by mixing biochar with compost raw material prior to composting. By the time composting is complete, the biochar pores should be fully loaded and ready to deliver microbes and nutrients to the plants.

We found a local source of compost (3xM Grinding & Compost LLC) outside Delta, Colorado. The biochar sold there is produced by others in the Rocky Mountain West with equipment from Biochar Solutions, Inc., headquartered in Lafayette, Colorado.

The biochar was mixed with compost feedstock prior to compost completion on site. Our order was relatively small: Six (6) yards each of 10% biochar 90% compost, 20% biochar 80%

compost and 100% compost. When the biochar was mixed with the unscreened, raw compost at 3xM, the base composting process was about 50% complete.

Each six (6) yard load fits nicely in a 6' x 12' dump trailer with 2' sides, slightly heaped. Three trips were necessary to move the mixes from 3xM to a staging area near Palisade, Colorado. The loads were transported on the following dates:

COMPOST /BIOCHAR %	TRANSPORT DATE
90/10	2/26/2021
80/20	3/2/2021
100/0	3/3/2021

For the 90/10 and the 80/20 loads, the 4-5 yards of compost required was culled from the large base compost conical pile and placed in small conical piles. Figure 1 illustrates the relative sizes of the large base compost pile and our 6-yard pile.

Figure 1. Compost and compost/biochar mixed piles.

The first two loads (90/10 & 80/20) were dampened a bit with water as they were dumped on the ground at the staging area near Palisade. The third load (100/0) was not dampened. On March 3, 2021, the temperatures of the three piles were measured with a 3 ft. long compost thermometer. The temperature of loads 1 and 2 were never higher than 75° F, whereas the temperature of load 3 was 145°F immediately after dumping. This apparent inactivity of loads 1 and 2 may be due to the following: a.) the water added contained chloramine and was cold, b.) the biochar absorbed the moisture and microbiomes thereby slowing the composting process, or c.) these loads were small and sat at 3XM for a few days before they were picked up. The much larger surface area to mass ratio of our small piles may have allowed the piles to lose heat more rapidly, especially at night, thereby slowing, or even extinguishing the composting process. In addition, the method of loading the dump trailer may have played a role, as described below.

The 100% compost load was extracted out of the base compost pile that was used to prepare loads 1 and 2. Loads one and two were disturbed much more when moved in multiple small bucket loads. The relatively undisturbed and un-watered 100% compost load at the Palisade staging site, was 145° F, and then was 112° F 12 days later.

The issues discussed above indicate that the most efficient way to make a compost/biochar mix may be in much larger piles with the biochar added at the very beginning of the composting process. Such large piles could then be screened in commercial-sized equipment, to remove the larger woody pieces. (Our three piles were mixed with raw, unscreened compost, with large pieces removed by hand during application.) Due to the currently low demand for biochar compost, this may not be practical until a larger demand is developed.

The total cost of the three piles of biochar/compost was $1,244.

Transportation of the compost from 3xM in Olathe to the staging area near Palisade and then transporting the various mixes to the test plots was donated.

Only about 20% of each of the three piles was applied to food plots in the Spring of 2021. What remained was left at the staging area and then covered with plastic tarps to stop growth of poverty sumpweed (*Iva axillaris* Pursh). The covered piles are shown at the staging area in Figure 2.

Figure 2. Piles of remaining compost/biochar mixes.

The piles remain in this state as of November 2021. It is not yet known how the placement of the tarps has or will affect the biological activity and pore loading of the compost/biochar piles.

Soil testing

We had compositional testing done on soils from both locations as well as the biochar compost mixes. Table 1 provides summary statistics for pH, organic matter, and soluble salts. The organic matter percentage includes the biochar. Unfortunately we do not have a value for the raw compost but the increase in organic matter between the 10% and 20% biochar mixes is 9.9%, very close to the 10% increase expected. The soil pH at Lobato Farms is somewhat higher than desirable. The Santa Fe Ranch HOA plots are in raised beds in boxes and have been regularly treated with organic material for at least the past 3 years, hence the high percantage of organic material.

Table 1. Soil, compost and biochar composition

site/compost	**sample type**	**pH**	**Organic Matter LOI%**	**soluble salts (mmho/cm)**	**Total carbon (%)***
Lobato Farms	soil	8.3	9.00	5.42	
Santa Fe Ranch HOA	soil	7.7	12.60	1.40	
3XM 10%	compost/ 10% biochar	7.6	24.70	8.62	21.8
3XM 20%	compost/ 20% biochar	8.1	34.60	8.39	24.4

Source: Testing by Ward Labs from samples sent in on March 18, 2021

*Total carbon testing was done February 2, 2022. The carbon percentage for just the compost was 14.8.

The soluble salts results by themselves are not very useful. Both beneficial and harmful salts (e.g., sodium, calcium, magnesium) can all contribute to the value. The Ward test breaks these out and Lobato's soil comes in in the acceptable range for sodium.

The CCA 20% biochar results might be more concerning. They are high in overall salts and in the WARD detailed results they are the highest in sodium. This might be reducing the yield potential for the higher biochar content.

Planting

Green Junction Farmstead provided us with the vegetable starter plants for the project, grown in their greenhouse from seed. We purchased four varieties, based on what was available as well as plant hardiness:

- Charger Chili Peppers
- Asian Eggplant
- Curly-leafed Kale
- Ace Bell Peppers

Our initial plan was to create four 8’ x 8’ “subplots,” each containing the following mixes of soil, detailed on page 3 of this report

1. 20% biochar mixed with compost
2. 10% biochar mixed with compost
3. Compost only
4. No amendments: this was the control

However, this plan was used only at Lobato Farms in Fruita.

GJF wished to do their own planting and care. They continued their practice of planting in rows with designated rows devoted to the biochar/compost mixes described above.

The Santa Fe Ranch HOA site (2 existing raised garden beds) allowed for two 4’ x 4’ subplots within each box (4 subplots across the 2 boxes). Each subplot is 1/4th the size of the Lobato Farms subplots. Each subplot contained each of the 4 biochar/compost mix amendments described above. Each subplot had two plants for each species except kale which had seven plants per subplot.

Subplot preparation was performed by CCA volunteers in March and April of 2021 with planting taking place on May 22, 2021, at both locations.

Figure 3. Lobato Farms Biochar Test Plot, June 25, 2021.

Figure 4. Santa Fe HOA, subplot 1 and 2.

CCA volunteers weeded the Lobato Farms test plots as needed and harvested twice per week throughout the season to the end of September. Santa Fe Ranch was harvested once per week.

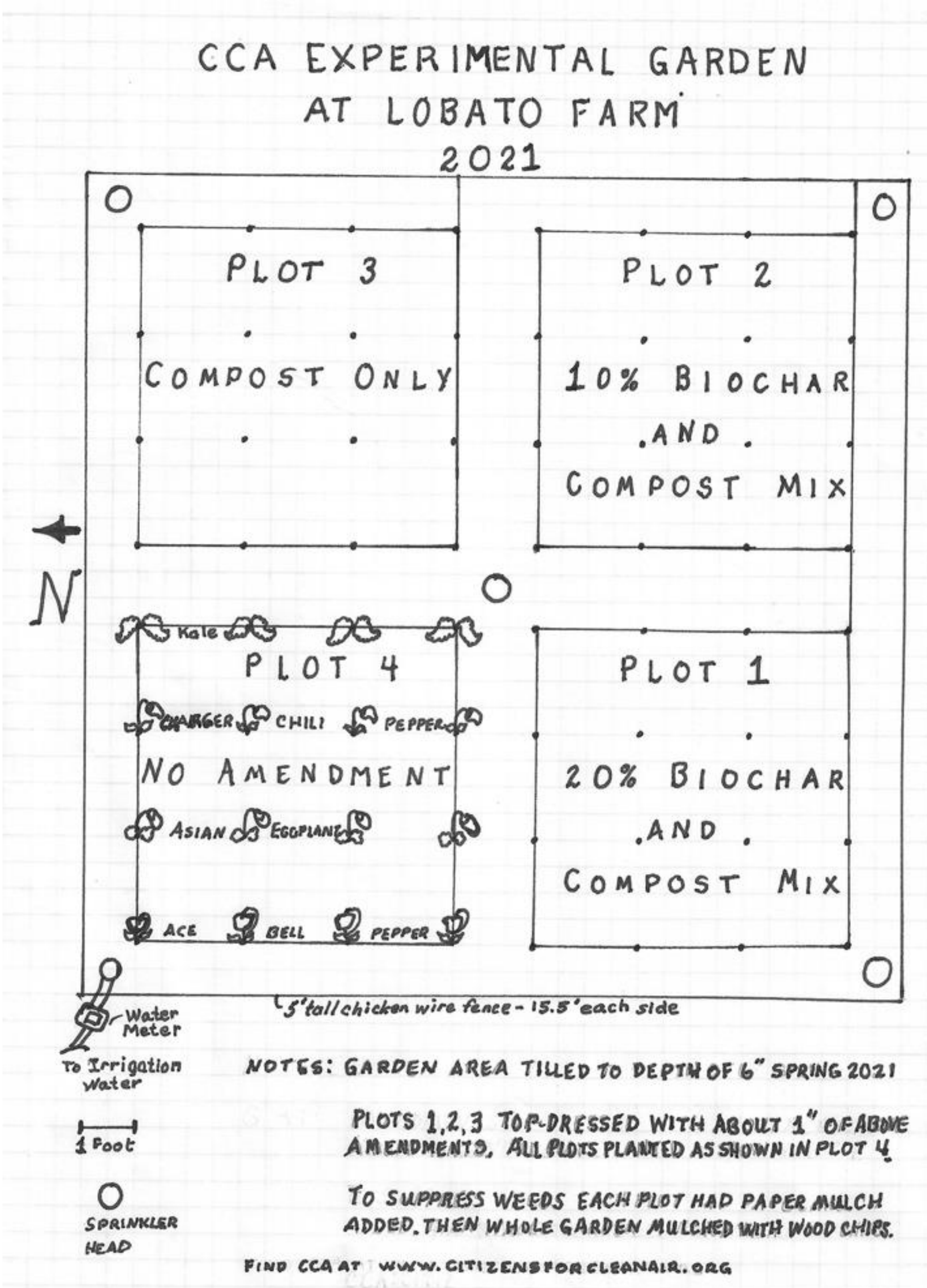
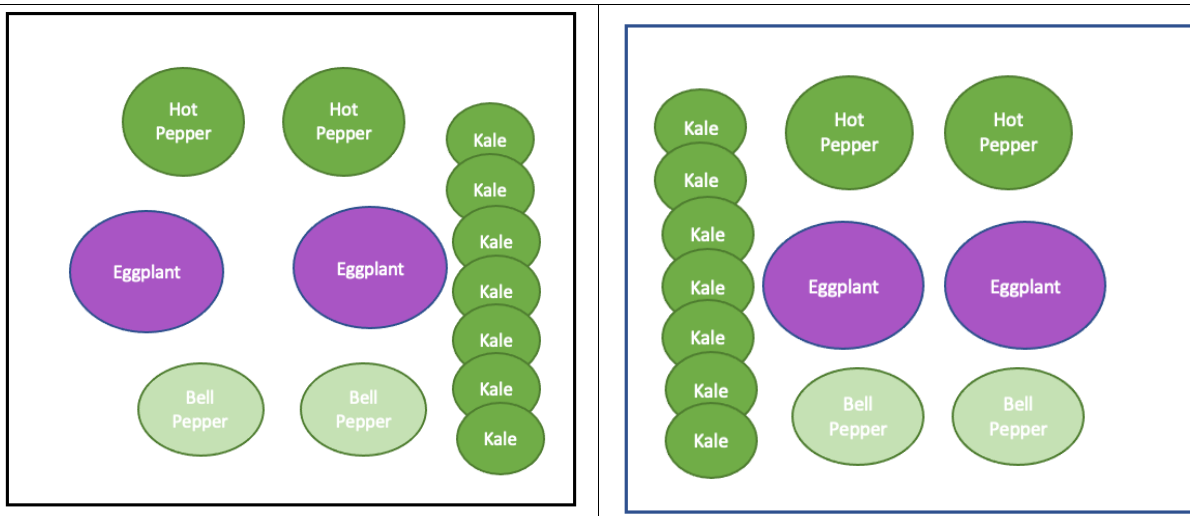


Figure 5. Layout of Lobato Farms test plots.



Layout for subplots 1 and 2 | Layout for subplots 3 and 4

Figure 6. Layout of Santa Fe Ranch HOA test plots.

Summary Production Statistics

Table 4 below presents the summary statistics of the weight of each crop in each subplot, as well as a comparison of the subplots with soil amendments to subplot 4, which contained no soil amendments. The subplot with the greatest harvest weight relative to subplot 4 is bolded below (Table 1), while the amended subplots with values less than subplot 4, are noted in red.

In all cases, the harvest weight from at least one of the amended plots, was greater than from subplot 4 (no amendment - the control). Subplot 2, which contained 10 percent biochar, yielded the largest produce weight for two of the four crops at Lobato Farms but none of the sub plots at the Santa Fe HOA. Subplot 1, which contained 20 percent biochar, yielded the greatest harvest weight for kale at Lobato Farms. The mixture of 20 percent biochar for both chili pepper and kale yielded the highest weight of produce at the Santa Fe HOA.

Since the Santa Fe HOA subplots were only ¼ of those in Lobato Farms but were planted more densely (half as many plants per plot) we expected less yield per plot. The results reported in Table 2 generally bear this out.

As noted above, the 20% biochar mix had high soluble salts and sodium which could reduce yields. We do in fact observe that the 20% yield results are often below the 10% yield results.

Lobato Farm	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**
Soil Amendment	**20% Biochar/Compost**	**10% Biochar/Compost**	**Compost Only**	**Control – No Soil Amendments**
Ace Bell Pepper				
Total (oz)	71.0	212.1	91.7	37.7
Relative to plot 4 (%)	189.0	**563.0**	244.0	100.0
Charger Chili Pepper				
Total (oz)	194.7	334.3	371.2	122.9

Relative to plot 4 (%)	158.0	272.0	**302.0**	100.0
Asian Eggplant				
Total (oz)	218.8	552.4	193.3	147.2
Relative to plot 4 (%)	149.0	**375.0**	131.0	100.0
Curly-Leafed Kale				
Total (oz)	197.5	195.0	156.8	184.2
Relative to plot 4 (%)	**107.0**	106.0	85.0	100.0
Santa Fe Ranch HOA	Plot 1	Plot 2	Plot 3	Plot 4
Ace Bell Pepper				
Total (oz)	31.7	18.4	33.9	27.9
Relative to plot 4 (%)	114.0	66.0	**122.0**	100.0
Charger Chili Pepper				
Total (oz)	90.3	63.6	51.7	52.7
Relative to plot 4 (%)	**171.0**	121.0	98.0	100.0
Asian Eggplant				
Total (oz)	32.0	63.2	98.9	71.5
Relative to plot 4 (%)	45.0	88.0	**138.0**	100.0
Curly-Leafed Kale				
Total (oz)	48.0	34.0	32.0	24.1
Relative to plot 4 (%)	**199.0**	141.0	133.0	100.0

Table 2. Summary Statistics- Production Quantity by crop and subplot.

Notes:

- Plot 1 is compost + 20% biochar, Plot 2 is compost + 10% biochar, Plot 3 is compost only, Plot 4 is no amendment.
- * Lobato Farms - One Ace pepper and one Asian eggplant in plot 3 died early in the season. The plants were wilted and the soil was drier in that area. A sprinkler head was adjusted to even out moisture. The plants were not replaced.
- * Santa Fe ranch - One of the eggplants in plot 1 did not make it, perhaps due to damage during transplant. The eggplant in plot 2 fell over, due to its enormous size, and was uprooted. Neighbors who live on the lot adjacent have a camper parked when they are not using it and it shaded plots 3 and 4 for a portion of the day.

Added Value from the Use of Compost and Biochar

Biochar and compost both have the potential to increase crop productivity in the short term and improve resilience by retaining soil moisture and nutrients in the long-term. As an added benefit, biochar also sequesters carbon for long periods of time because biochar is primarily elemental carbon that is not easily converted to CO_2 by soil microorganisms.

However, it is possible to calculate the market value of the additional harvest using prices received locally for some sales in September.

Lobato Farms					
CROP	PLOT 1	PLOT 2	PLOT 3	PLOT 4	SUBTOTAL
Bell Pepper ($)	$ 4.40	$ 13.30	$ 5.70	$ 2.40	$ 25.80
Chili Pepper ($)	$ 12.20	$ 20.90	$ 23.20	$ 7.70	$ 64.00
Eggplant ($)	$ 13.70	$ 34.50	$ 12.10	$ 9.20	$ 69.50
Kale ($)	$ 98.70	$ 97.50	$ 78.40	$ 92.10	$ 366.70
Total Value per Plot ($)	**$ 129.00**	**$ 166.20**	**$ 119.40**	**$ 111.40**	**$ 526.00**
Santa Fe Ranch HOA					
CROP	PLOT 1	PLOT 2	PLOT 3	PLOT 4	SUBTOTAL
Bell Pepper ($)	$ 2.00	$ 1.20	$ 2.10	$ 1.70	$ 7.00
Chili Pepper ($)	$ 5.60	$ 4.00	$ 3.20	$ 3.30	$ 16.10
Eggplant ($)	$ 2.00	$ 4.00	$ 6.20	$ 4.50	$ 16.70
Kale ($)	$ 24.00	$ 17.00	$ 16.00	$ 12.10	$ 69.10
Total Value per Plot ($)	**$ 33.60**	**$ 26.20**	**$ 27.50**	**$ 21.60**	**$ 108.90**

Table 3. Estimated value of production per crop and subplot USD ($).

Note: Prices used for value calculation reflect rough wholesale value in September 2021. Kale, $8 per lb. Other crops, $1 per lb.

For both locations, using the amendments generated higher yields and the potential for more revenue. The plots containing biochar (1, 20% biochar and 2, 10% biochar) also had higher value of output than the compost only plot 3 at the Lobato Farm. Plot 3 did slightly better overall at Santa Fe than plot 2. The results for individual crops differ somewhat from the overall results. But only in one case (kale at Lobato's) did plot 4 (no amendments) do better than an amended plot (plot 3). These results provide some initial confirmation of the value of using compost with biochar added.

Post-harvest Root Structure

One element of successful plant growth is a well-developed root structure. At the end of the harvest period, we pulled up one root ball for each crop in each of the plots (Figure 7). We didn't do any quantitative analysis of root mass, but qualitatively it appears that the plants in the compost plus 10% biochar plot had the most vigorous root structure.

Figure 7. Root structure by crop and plot

Soil Biological Activity – Haney Test Results

A healthy soil microbiome can contribute to significant improvements in crop productivity. The Haney test provides a quantitative assessment of the biological activity in a soil sample. Soil microbes breathe in oxygen and release carbon dioxide (CO_2). The Haney test measures how much CO_2 a soil is releasing. Higher CO_2 levels indicate more microbial activity.

Soil profile composite samples (0-to-6-inch depth) were collected from the Lobato Farms test plots and submitted to Ward Labs (Kearney, Nebraska) for a battery of soil health measurements. The measured parameters included soil microbial activity and nutrient levels, which were used to calculate a soil health index.

The soil health parameters correlated well with crop yields. The soil without any amendments is relatively healthy with high microbial respiration and nutrient levels. Adding mulch to the original soil improved the soil health and crop yields. The addition of mulch with 10% biochar produces an even greater increase in crop yield and soil health, but the addition of mulch with 20% biochar dropped soil health and crop yields to values similar to that of the original soil. One possible reason for this decrease in the mulch + 20% biochar plot is that the biochar boosted microbial activity to the point where accessible organic carbon was depleted and soil productivity declined.

Soil Respiration

The soil respiration test determines the amount of CO_2 that is emitted from the soil over a 24-hour period under controlled laboratory conditions. The amount of CO_2 is a measure of the microbial activity in the soil. The more CO_2 a soil produces the greater the microbial biomass. Microbial activity is important because it is tied to many functions of a healthy soil such as nutrient cycling, soil aggregate and organic matter formation, disease suppression and stimulation of plant growth.

Soil respiration readings can range anywhere from near zero to 1000 ppm of CO_2. Most agricultural soils are less than 200 ppm. In general, the higher the number the better, as soil respiration is considered a strong indicator of overall soil biological function.

Respiration rates for the Lobato Farms plots were 120 for no soil amendment and 136 with compost only, which is categorized as "high" and greater carbon input may be needed to sustain this level of biological activity. The compost + 10% biochar plot jumped to a respiration rate of 263, which is "very high" and indicates that carbon level could ultimately limit production. A noticeable decrease in respiration was observed in the compost + 20% biochar plot to 77, a level defined as "above average".

Soil Health Score

The soil health score is a summary of the soil respiration, water extractable organic carbon (WEOC) and water extractable organic nitrogen (WEON) and represents the current health level of the soil. WEOC and WEON values are indicative of the amount of carbon and nitrogen that are available for microbial growth. The score can range anywhere from 0 to 50, but most soils do not score higher than 30. In general, the higher the score the better. As in the case of soil respiration, relative soil health scores were highest in the compost + 10% biochar plot followed by compost only with no amendment, and lowest in the the compost + 20% biochar plot.

Microbially Active Carbon (%MAC)

Microbially active carbon or %MAC is how much of the WEOC pool was consumed by the microbes during the soil respiration test. If this value is below 25% WEOC is probably not the factor limiting soil respiration. %MAC value above 80% indicate that WEOC could soon become limiting to microbial respiration and additional carbon is needed in the soil to sustain this level of activity. For most agricultural soils the ideal %MAC levels are between 50 and 75%. This indicates that the soil has a good balance of fertility and WEOC to support microbial biomass, but the pool of WEOC is not limiting.

The no amendment and compost only plots were within the ideal %MAC range, while the value for compost + 10% biochar soil was near 100% indicating that the available organic carbon (WEOC) had been exhausted during the test. The compost + 20% biochar value was below the ideal range for %MAC.

Soil Treatment / Parameter	20% biochar + compost	10% biochar + compost	compost	no amendments
Soil Respiration (ppm CO2 24 hr)	77	263	136	120
Soil Health Index	15	27	19	17
Total Crop Yield (lbs)	43	81	51	31
% MAC	35	103	58	59

Table 4. Soil Health Values for Lobato Farms Plots

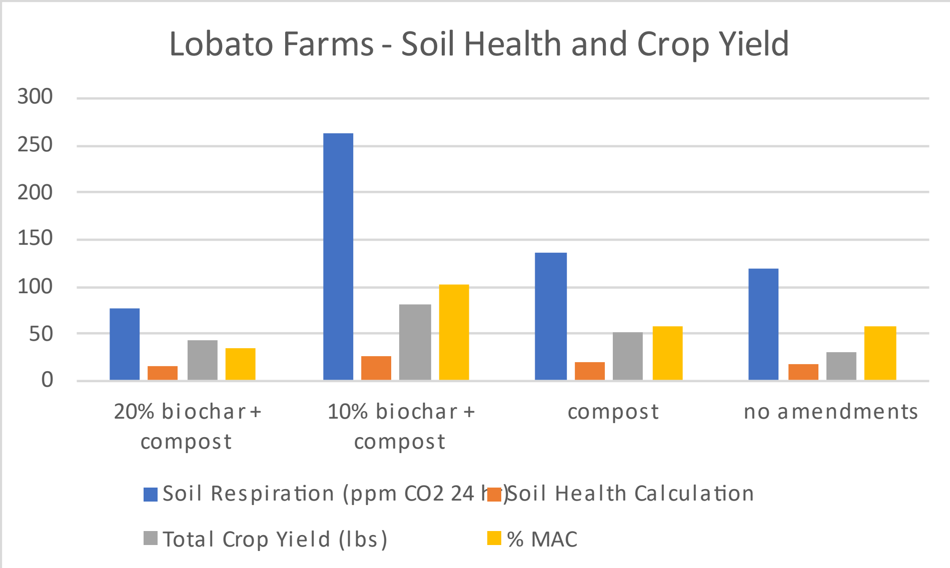


Figure 8. Soil Health Values for Lobato Farms Plots

Non-Carbon and Non-Nitrogen Nutrient Levels

Nutrients other than WEOC and WEON are critical to soil health and productivity. Values for these nutrients were all in the category of "Very High Soil Fertility" for all the Lobato Farm plots (Table 5). There was no indication that the addition of biochar to the soil amendments decreased the overall level of nutrient values. This is an important observation because there have been reports of unconditioned biochar (not being equilibrated with active compost) depleting soil nutrients via sequestration. It appears that the biochar used in the testing was adequately "loaded" from the compost admixture.

Nutrient (ppm)	20% biochar + compost	10% biochar + compost	compost	no amendments	"Very High" Category for Soil Fertility Rating
Total Phosphorus	118	256	222	286	>106
Potassium	666	419	611	717	>90
Iron	53	73	72	58	>20
Sulfur	70.6	111.3	83.3	106.2	>15
Zinc	1.45	1.45	1.17	1.46	>0.5
Manganese	10.7	4.2	8.6	5.4	>3
Copper	0.64	0.26	0.32	0.46	>0.2
Magnesium	301	412	329	349	>30

Table 5. Non-Carbon and Nitrogen Nutrient Levels for Lobato Farms

Equipment Used in This Experiment

For field preparation and planting

- Fence stakes
- Chicken wire
- Plastic ties
- Flags
- Plot divider material: wood chips
- Ground cover for weed control
- Sprinkler drip system at Santa Fe Ranch provided in kind
- Sprinkler spray system at Lobato Farms provided in kind
- Shovel, hoe, volunteers provided their personal garden tools and work gloves
- Signage for each site: one educational 12x18" for the public and four 6x8" color-coded ID markers for each plot

For in-season management at each location

- Scale to weigh harvest (able to compensate for weight of container *tare weight*
- Containers for weighing harvest
- Soil moisture meter
- Water volume meter
- Data recording sheets, clipboard, writing utensils, eraser, scissors for cutting fruit, separate bags for harvesting each subplot
- Large container for supplies to keep on site

Lessons Learned

- Perform soil testing at the beginning and end of each season.
- A scale larger than the one used during the 2021 season would make weighing easier. Large containers for weighing harvest may be preferable to smaller containers.
- Begin recruiting volunteers earlier (January/February).
- Educate volunteers before the project starts (recorded webinar?) Make webinar available to newcomers on website.
- Have a booklet at each site with clear instructions for each activity.
- Include a plot map where each plant is to be planted.
- Recruit two organizers to help volunteers, answer volunteer questions, replenish supplies, visit sites, keep in touch with owners of properties, etc.
- Create an "Agreement" between property owners and CCA outlining expectations (space required, water needs, easy volunteer access, harvesting and weighing process etc.)
- Grow the same or different crops next year? Start preparing purchase of plants in January.
- Sprinkler drip system is ideal, but costly.
- Consider branching out to commercial farms growing corn, wheat, etc.

Educational Outcomes

Part of CCA’s intent is to help educate farmers, gardeners, and the public about the potential benefits of biochar. Cross Orchards and the fairgrounds were of particular interest due to the exposure these sites offer to the public but in the end didn’t work out.

However, we discovered the locations highlighted above provided unexpected public educational outcomes.

The farmers and HOA gardener who provided plot space were greatly interested in the process and outcomes of the study and contributed their experience and general knowledge to the effort. The HOA and Lobato Farm sites shared and/or sold their harvests. Neighbors and friends became curious about the experiment with Lobato neighbors requesting information on the availability of biochar for their own use next year.

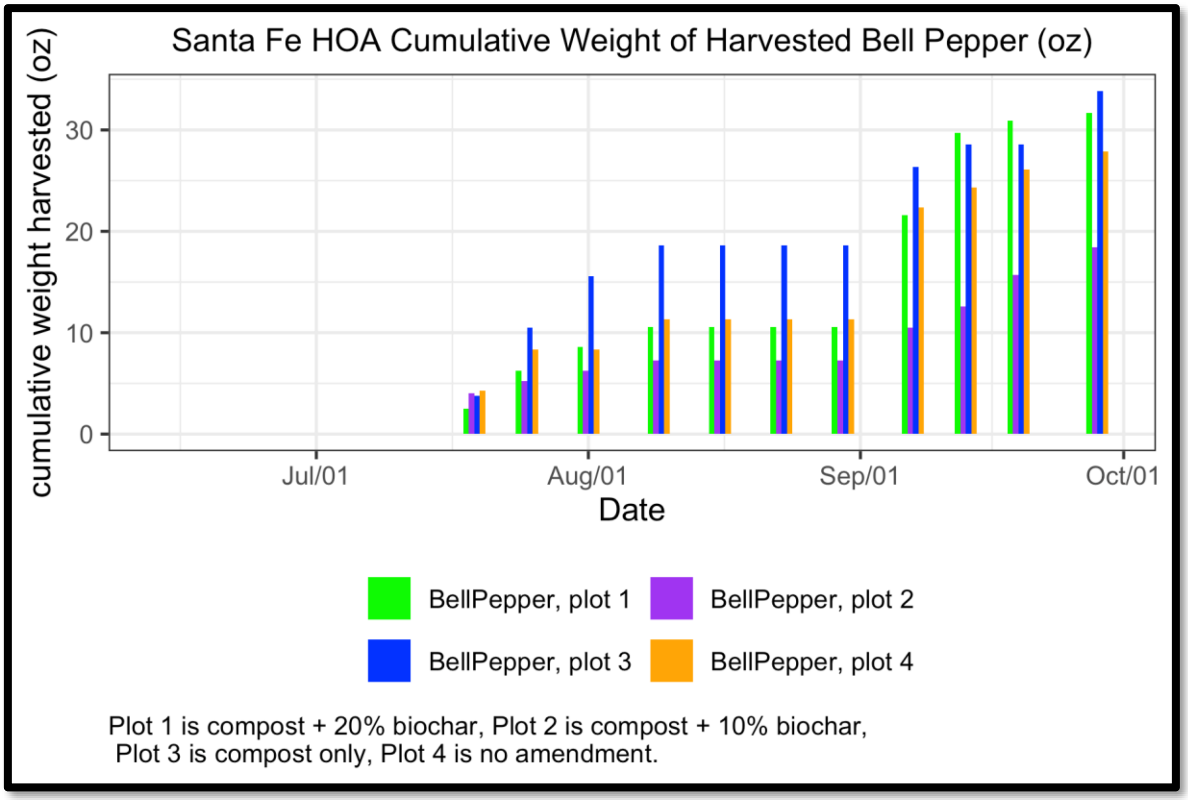
In addition to providing our email list of approximately 250 recipients with updates and newsletter information, we created a page on our website with a basic factsheet, power point presentation and other additional information on biochar.

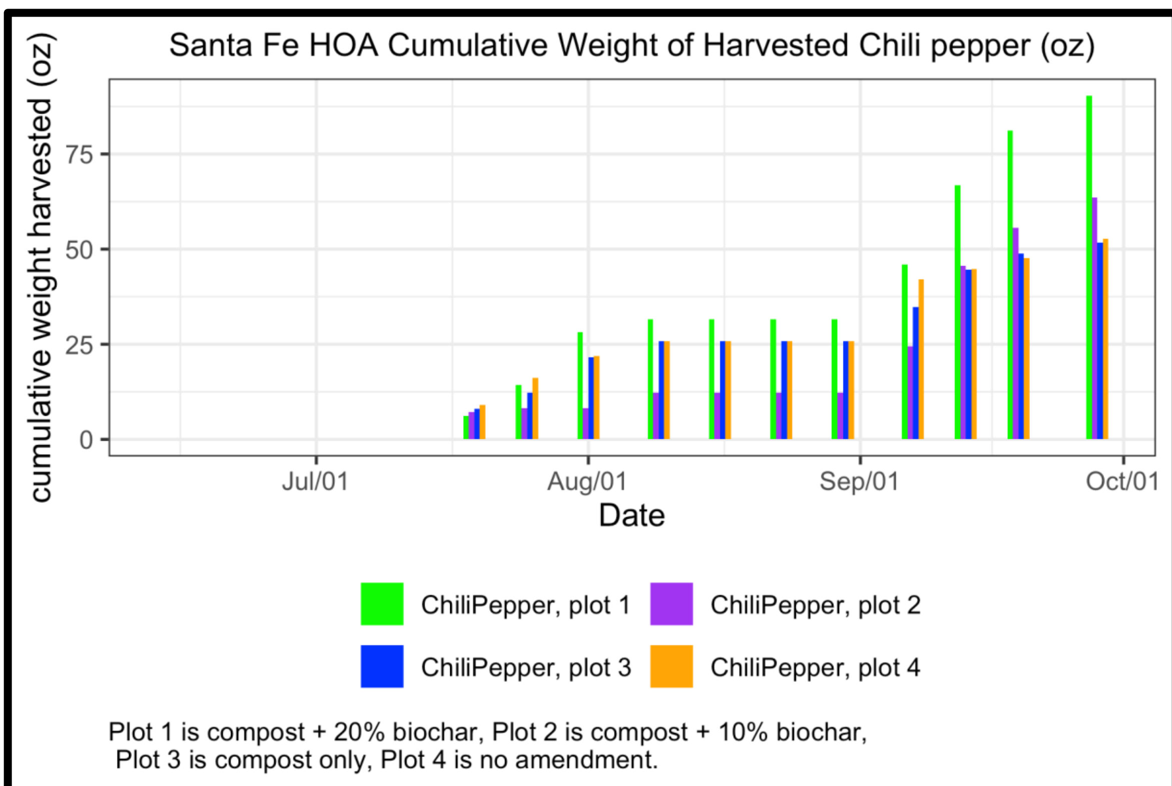
Most of all, some dozen volunteers from our email list and beyond stepped up to participate in the planning, planting, care, harvest, and data collection. Their involvement and keen observations in the process were essential to the objectives of the study.

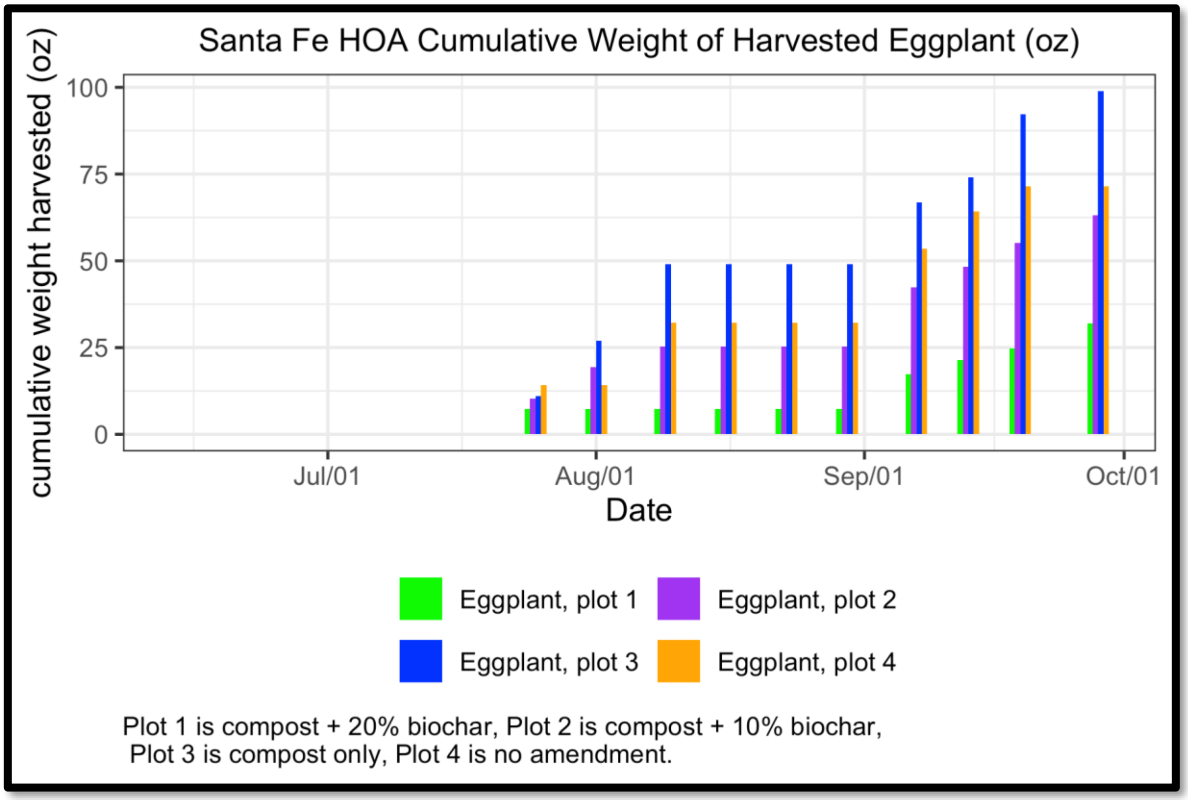
Harvest Progress Figures

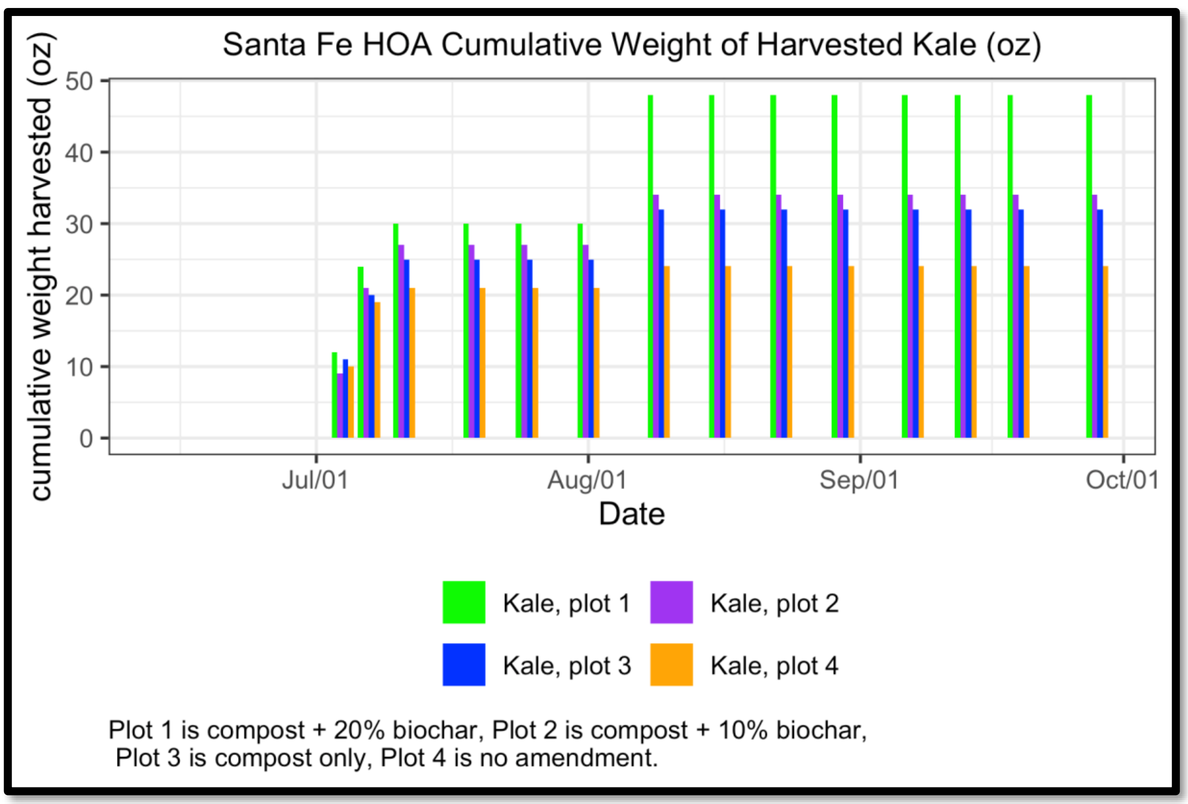
The graphics on the following pages show the harvest progress.

Harvest Progress Graphics, Santa Fe Ranch HOA

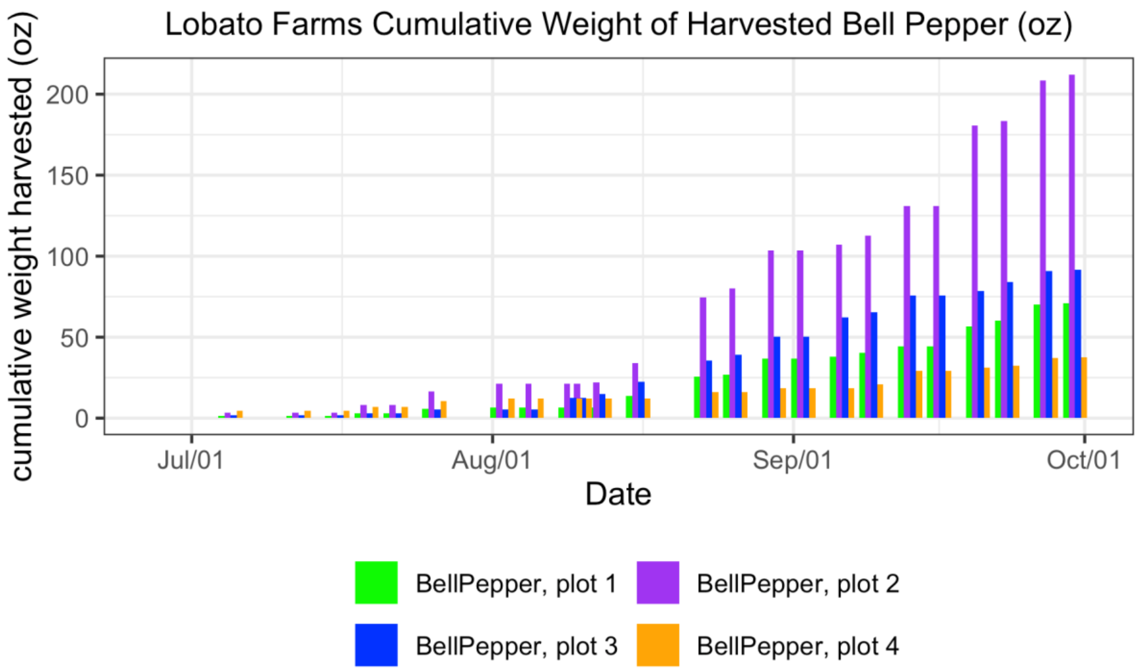




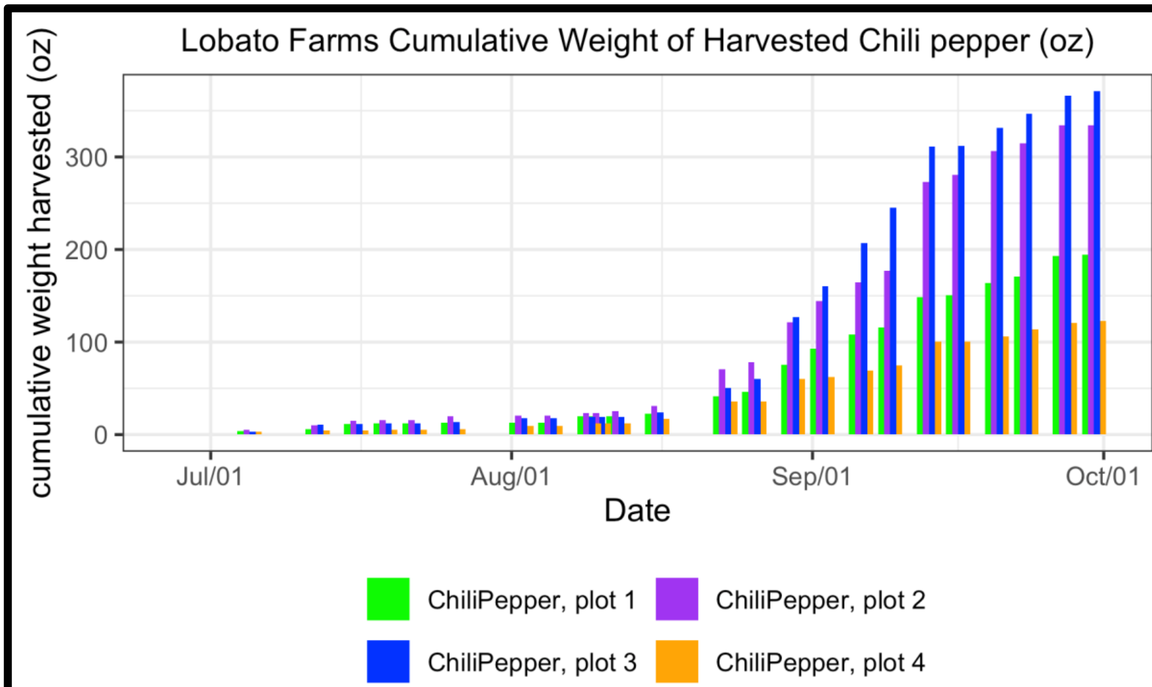

Santa Fe HOA Cumulative Weight of Harvested Eggplant (oz)
cumulative weight harvested (oz)
100
75
50
25
0
Jul/01
Aug/01
Sep/01
Oct/01
Date
Eggplant, plot 1
Eggplant, plot 2
Eggplant, plot 3
Eggplant, plot 4
Plot 1 is compost + 20% biochar, Plot 2 is compost + 10% biochar,
Plot 3 is compost only, Plot 4 is no amendment.


Santa Fe HOA Cumulative Weight of Harvested Kale (oz)
cumulative weight harvested (oz)
50
40
30
20
10
0
Jul/01
Aug/01
Sep/01
Oct/01
Date
Kale, plot 1
Kale, plot 2
Kale, plot 3
Kale, plot 4
Plot 1 is compost + 20% biochar, Plot 2 is compost + 10% biochar,
Plot 3 is compost only, Plot 4 is no amendment.

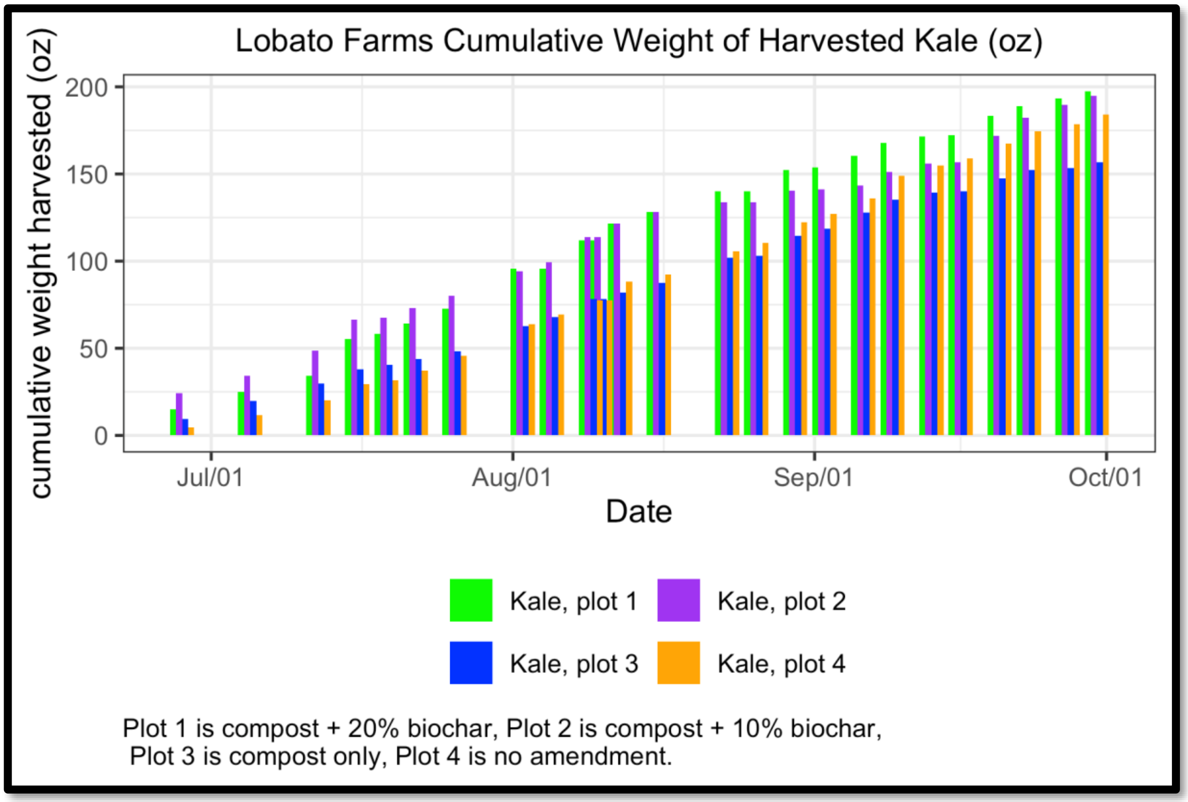
Harvest Progress Graphics, Lobato Farm

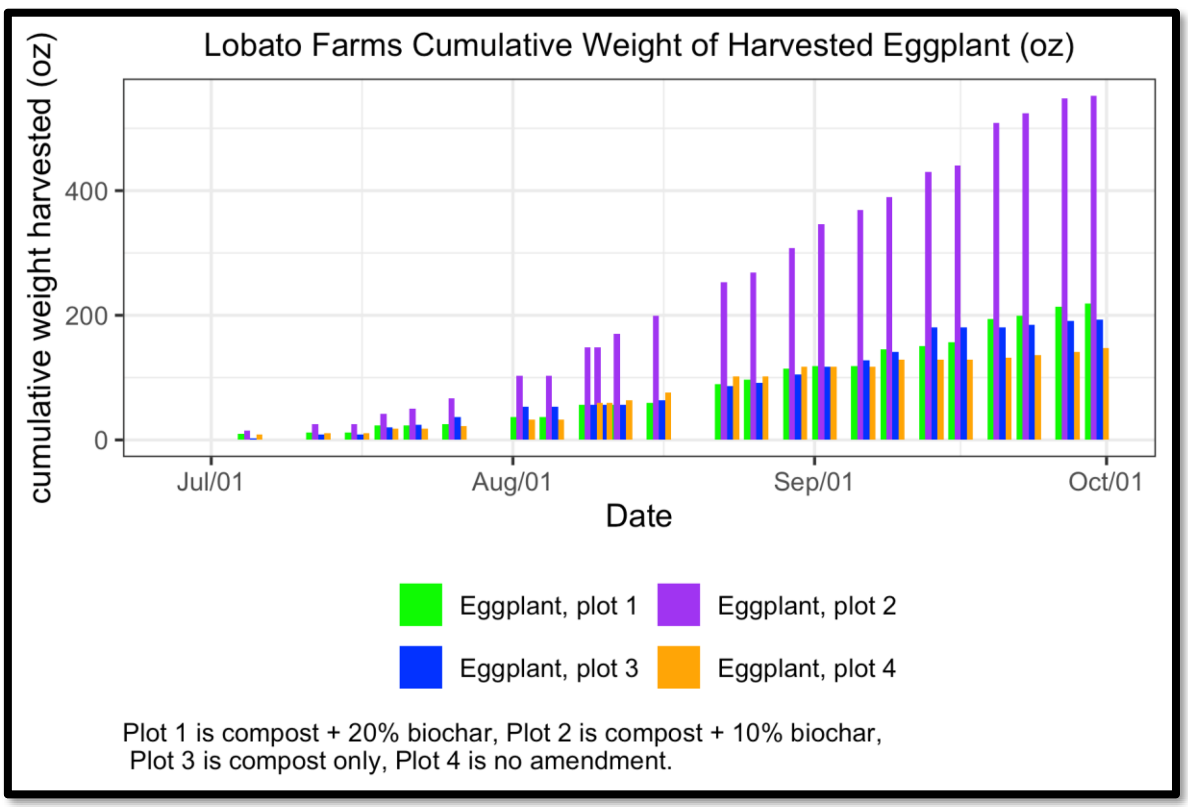


Plot 1 is compost + 20% biochar, Plot 2 is compost + 10% biochar, Plot 3 is compost only, Plot 4 is no amendment.



Plot 1 is compost + 20% biochar, Plot 2 is compost + 10% biochar, Plot 3 is compost only, Plot 4 is no amendment.


Lobato Farms Cumulative Weight of Harvested Kale (oz)
cumulative weight harvested (oz)
200
150
100
50
0
Jul/01
Aug/01
Sep/01
Oct/01
Date
Kale, plot 1
Kale, plot 2
Kale, plot 3
Kale, plot 4
Plot 1 is compost + 20% biochar, Plot 2 is compost + 10% biochar,
Plot 3 is compost only, Plot 4 is no amendment.


Lobato Farms Cumulative Weight of Harvested Eggplant (oz)
cumulative weight harvested (oz)
400
200
0
Jul/01
Aug/01
Sep/01
Oct/01
Date
Eggplant, plot 1
Eggplant, plot 2
Eggplant, plot 3
Eggplant, plot 4
Plot 1 is compost + 20% biochar, Plot 2 is compost + 10% biochar,
Plot 3 is compost only, Plot 4 is no amendment.

Photographs of the Project

Figure 9. Soil preparation and chicken wire fence installation at Lobato Farms.

Figure 10. Lobato Farms left: subplot w/ 10% biochar; right: subplot w/ 0 amendments (control)

Figure 11. Lobato Farms harvest July 26, 2021.

Figure 12. Santa Fe Ranch harvest (probably July).