THE EFFECT OF INCREASING RATES OF BIOCHAR ON CORN GROWN IN SALINAS CLAY LOAM

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By

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ABSTRACT

In order to sustain the ever growing global population, agriculture needs to not only increase yields but to increase yields in a way that is sustainable and is either environmentally neutral or has a positive effect on the environment. Biochar offers a solution to this challenge with numerous environmental benefits, as well as agricultural benefits (Lehman and Joseph 2009). The agricultural benefits of biochar have been well documented in tropical climates, with the benefits of biochar for other climates, such as temperate climates and Mediterranean climates, relatively unknown (Blackwell et. al. 2009). To determine the effect of biochar on agricultural soil in the Mediterranean climate of California's Central Coast, a greenhouse trial growing corn was set up to compare the effect of three different rates of biochar, .25, .5, and .75 tons/acre, to corn that was grown without a biochar amendment. The corn plants were allowed to grow for eight weeks before being harvested and tested to determine the following: dry weight (g), moisture (%), nitrogen (%), phosphorous (%), potassium (%), zinc (mg/kg), manganese (mg/kg), boron (mg/kg), calcium (%), magnesium (%), iron (mg/kg), copper (mg/kg), sulfur (%), aluminum (mg/kg), and molybdenum (mg/kg). The testing revealed that there was no significant difference for any of the metrics that were tested for any rate of biochar.

Key Words: Biochar, soil fertility, environmental, agricultural sustainability, corn.

DISCLAIMER

This project is original work done through Cal Poly, San Luis Obispo, by the author, Joshua Fridlund, under the guidance of advisors, Dr. Vaughan and Dr. Flores.

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INTRODUCTION AND PURPOSE

The purpose of this senior project was to determine the affect of using biochar as a soil amendment with regards to crop production, specifically corn, on the Central Coast of California through a controlled greenhouse trial. Biochar has been shown through research to have potential to increase yields through a combination of direct nutrient value, increasing nutrient availability, liming potential, toxin neutralization and improving soil physical properties. These agricultural benefits along with the known environmental benefits of biochar, such as carbon sequestration, reduction of leaching and the previously mentioned toxin neutralization, could allow biochar to become a vital part for improving the sustainability of agriculture (Lehman and Joseph 2009). However, most research on agriculture productivity is derived from tropical climates (Blackwell et. al. 2009). Tropical climates vary greatly from the Mediterranean climates found on the Central Coast of California and, as such, the effect of biochar on agriculture productivity for this region is unclear. To this end this study was conducted to determine whether using biochar as a soil amendment would be a beneficial or detrimental to yield for this soil, and whether the amount of biochar applied had an effect, was the goal of the project. The variable that was examined was rate of biochar application.

LITERATURE REVIEW

What is Biochar?

Biochar is the result of putting biomass, such as plant material or manure, through a process called pyrolysis in which it is heated with little to no oxygen, normally at temperatures less than 700° C. This creates a soil amendment that has been linked to increased soil productivity, carbon storage, and water filtration (Lehmann and Joseph, 2009). The difference between biochar and charcoal, which is produced through nearly identical means, is that biochar is created for the purpose of amending soil for the benefits of increased soil productivity, carbon sequestration and water filtration (Lehmann and Joseph, 2009).

Biochar has been receiving increased attention as an agricultural supplement not only for the direct agricultural benefits, but also because of the positive environmental potential of biochar. This is due to its nature of being carbon-neutral and carbon-negative due to the production process and its subsequent application as a soil amendment (Lehman, 2007). From a production standpoint biochar not only does not give off the same CO_2 emissions as normal disposal methods of biomass but the process of creating biochar is exothermic and can be harnessed to produce energy (Lehman, 2007). As a soil amendment biochar is an incredibly stable form of carbon in soil. This makes biochar unique as an organic matter soil amendment as biochar will not be quickly broken down and has the potential as a long term carbon storage solution (Lehman, 2007). As an agricultural soil amendment biochar has been shown to have a variety of benefits such as increased nutrient uptake, decreased disease susceptibility and better soil structure (Lehmann and Joseph, 2009).

Physical Properties

Much of biochar's potential for both agriculture and environmental use comes from its physical structure. Biochar is made up of irregularly arranged carbon, hydrogen and oxygen molecules with the potential to include additional minerals based on the parent material that the biochar is derived from (Lehman and Joseph, 2009). This gives biochar a porous nature that gives the material very high surface area that allows for increased water holding capacity and increased impact in binding of valuable nutrients, in the form of cations and anions (Atkinson et al, 2010). Biochar also possess macropores, greater than 50nm in diameter, which aids in soil aeration (Sohi et al., 2010)

Chemical Properties

Chemically biochar is hard to define as the chemical makeup varies depending on the source material used to produce it as well as the method in which the char is produced (Amonette and Joseph, 2009). More specifically biochar created under low heat conditions, less than 500° C, has a low cation exchange capacity (Lehman, 2007). As the temperature of pyolysis increases so does the Cation Exchange Capacity (CEC), of the resulting biochar (Lehman, 2007). Nutrient availability also varies with the temperature of pyrolysis. For example the percent phosphorus increased dramatically, from 5 to 12%, as the temperature of pyrolysis is increased from 250 to 800° C (Shinogi, 2004). Nitrogen on the other hand decreases from 4 to 2% as the temperature is increased from 400 to 800° C (Shinogi, 2004).

There are three characteristics that are common across all biochars, though the strength of the characteristic still varies based on parent material (Lehman and Joseph, 2009).The first characteristic of biochar is of course is high carbon content, ranging from 172 to 905g per kilogram depending on the source of the biomass (Chan and Xu, 2009). It's this high carbon content when combined with the biochar's stability in the soil that gives biochar the potential to increase carbon storage (Lehman, 2007). The second characteristic is the high stability of biochar in the soil. Carbon stored in soil as biochar has been projected to have a life span of at least several hundred thousand years (Lehmann, 2007). The final chemical characteristic of biochar is that biochar is superior to other forms of organic matter when it comes to nutrient retention (Lehmann, 2007).

Biochar and Soil Fertility

Soil fertility in the most basic sense is the ability of the soil to provide plants with nutrients. However from an agricultural, environmental and conservation perspective soil fertility is so much more. A more complete definition of soil fertility is that soil fertility is the ability of the soil to supply mineral nutrients to plants, the mechanisms by which nutrient supply occurs, the factors which affect the supply of nutrients to plants and the influence of the soil plant system on the environment (Smith, 2014). Biochar helps to increase soil fertility from an agricultural perspective by reducing soil acidity, improving soil CEC, improving soil water holding capacity and improved habitat for beneficial microorganisms in the soil (Blackwell et. al. 2009) From an environmental perspective, biochar also improves soil fertility by reducing the risk of pollution by intercepting leachable nutrients and toxic chemicals such as pesticides (Blackwell et. al. 2009).

MATERIAL AND METHODS

Material: Biochar and Soil

The amending material is a high-carbon biochar derived from the pyrolysis of wood waste and provided by Alterna Energy, Inc. Metal content of the biochar was determined by the Alterna Energy Labs. The feedstock was a mix of spruce, pine, and fir which was pyrolized at 420 °C using the Van Aardt process (van Aardt et al., 2010).

The soil used in this experiment was Salinas series silty clay loam soil, a Fine-loamy, mixed, superactive, thermic Pachic Haploxerolls (Appendix B). The soil was collected by random sampling of the top 12 inches of soil of field 35A on the California Polytechnic State University campus.

Growth Trial

The trial consisted of growing corn plants in terra cotta pots, indoors under grow lights. Four different rates of biochar application, 0, .25, .5 and .75 tons/acre equivalent, were used for the trial. Each rate had four replicates and each replicate had six corn seeds planted to ensure the necessary successful germination. After one week each pot was thinned as needed down to four corn plants. The plants were regularly watered and harvested at eight weeks. The plants were then sent to Dellavalle Laboratory Inc. where each plant was analyzed individually.

Dry Matter Content

Dry matter content of the plant samples was determined using the Determination of Dry Matter Content of Botanical Materials B: Gravimetric Moisture, method P1.10 of the Soil, Plant and Water Reference Methods for the Western Region (Gaylak et al, 2005). Approximately 2g of the air dried samples were weighed out into a tared aluminum pan. The samples were then placed into a drying oven at 105°C for a minimum of 2 hours. The samples were then placed in a desiccator for 1 hour. The samples were then weighed again to determine the sample dry weight. Percent dry weight was then calculated using the following equation.

$$\text{Sample dry matter \%} = \frac{(\,1 - (\text{Sample moist wt.}) - (\text{sample dry wt.} - \text{pan tare wt.}\,)\,) \times 100}{(\text{Sample dry weight} - \text{pan tared weight})}$$

Total Nitrogen

Total Nitrogen was determined using the Total Nitrogen in Botanical Materials: Automated Combustion Method, method B-2.20 of Soil, Plant and Water Reference Methods for the Western Region (Gaylak et al, 2005). Samples weighing 150mg +/- 5mg, that had been pulverized to pass through a 40 mesh sieve, were placed into a tared tin foil container, encapsulated and the weight recorded. Samples were then analyzed with a LECO nitrogen analyzer according to manufacturer specifications.

Elemental Analysis

The amount of these elements in the samples was determined using a modified version of the Nitric/Perchloric Acid Digest, method B 4.20 of the Soil, Plant and Water Reference Methods for the Western Region (Gaylak et al, 2005), which used hydrogen peroxide instead of perchloric acid. 500.0 mg, ± 0.5 mg, of sample was weighed into a 50 ml volumetric digestion tube. 6.0 mL of nitric acid and a Teflon boiling chip were then added to the samples. Samples were then swirled to thoroughly wet the samples. The samples were then covered and allowed to predigest over night. They were then placed on a digestion block for thirty minutes at 80 °C. Samples were then cooled to room temperature and then 3ml of 30% H_2O_2 was then added 1 ml at a time. Samples were then placed back in the block at 120 °C for thirty minutes. Samples were then removed from the digestion block, and allowed to cool in a hood. Samples were then brought up to final volume with deionized water, mixed and then filtered. The solution was then analyzed using a Perkin-Elmer ICP. Percentages were then calculated using the following equation:

$$\%\text{ analyte} = \frac{(\text{Lmg - method blank}) \text{ x } (50) \text{ x } (0.0001)}{\text{Dry matter } (\%)\ 100}$$

Milligrams per kilogram (parts per million) were then calculated using the following equation:

$$\text{Mg/kg analyte} = \frac{(\text{Lmg - method blank}) \text{ x } (50)}{\text{Dry matter } (\%)\ 100}$$

RESULTS AND DISCUSION

Through the data collected from the sixteen different metrics that were measured, a clear picture emerges. For each metric, the sixteen samples for each rate were averaged after removing any outliers (Table 1).

Table 1. The average effect of different rates of biochar upon sixteen metrics of plant productivity and health

Rate of Biochar	0 tons/acre	.25 tons/acre	.5 tons/acre	.75 tons/acre
Dry Weight(g)	.50	.63	.51	.50
Dry Weight (%)	8.58	9.73	8.34	7.93
Moisture (%)	91.42	90.27	91.66	92.07
Nitrogen (%)	1.83	1.49	1.52	2.09
Phosphorous(%)	.3	.31	.29	.31
Potassium (%)	4.79	4.72	4.86	5.07
Zinc (mg/kg)	46	30	39.25	35.25
Manganese (mg/kg)	35.6	31.56	34.81	37.81
Sodium (%)	.02	.02	.02	.03
Boron (mg/kg)	20.81	18.31	19.38	23
Calcium (%)	.33	.33	.36	.35
Magnesium (%)	.41	.37	.41	.42
Iron (mg/kg)	294.2	224.56	312.81	282.94
Copper (mg/kg)	8.06	6.5	9.88	9.63
Sulfur (%)	.18	.15	.16	.2
Aluminum (mg/kg)	116.75	87.04	141.17	119.26
Molybdenum (mg/kg)	.98	.76	.61	.69

None of the rates show a significant difference, meaning data outside of two standard deviations from the average. The lack of significant difference becomes even more apparent when the data is displayed graphically (Fig 1-16).

Fig 1.The effect of increasing rates of biochar on plant dry weight.

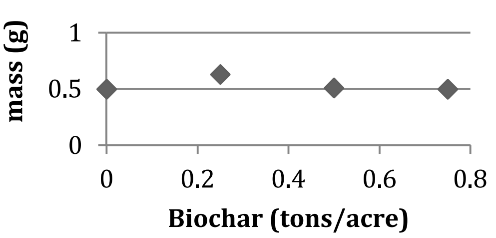


Fig 2.The effect of increasing rates of biochar on plant moisture.

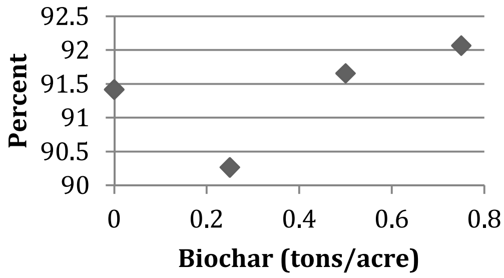


Fig 3.The effect of increasing rates of biochar on plant percent nitrogen.

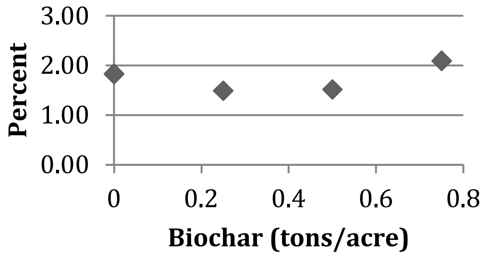


Fig 4.The effect of increasing rates of biochar on plant percent phosphorus.

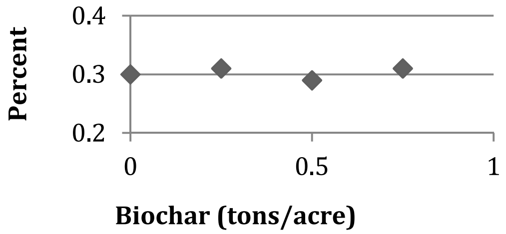


Fig 5.The effect of increasing rates of biochar on plant percent potassium.

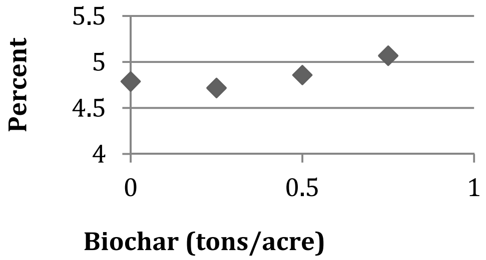


Fig 6.The effect of increasing rates of biochar on plant parts per million zinc.

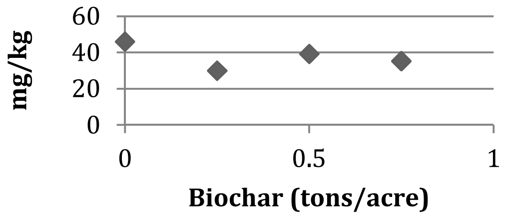


Fig 7.The effect of increasing rates of biochar on plant parts per million manganese.

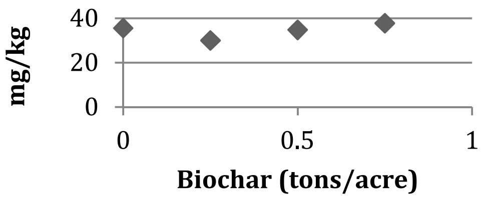


Fig 8.The effect of increasing rates of biochar on plant percent sodium

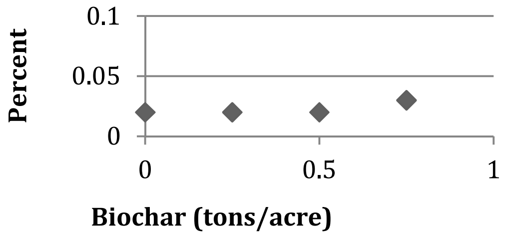


Fig 9.The effect of increasing rates of biochar on plant parts per million boron.

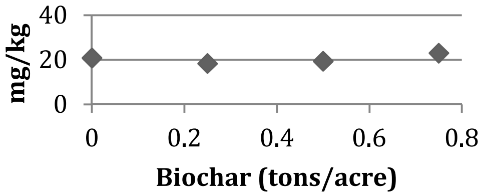


Fig 10.The effect of increasing rates of biochar on plant percent calcium.

Fig 11. The effect of increasing rates of biochar on plant percent magnesium.

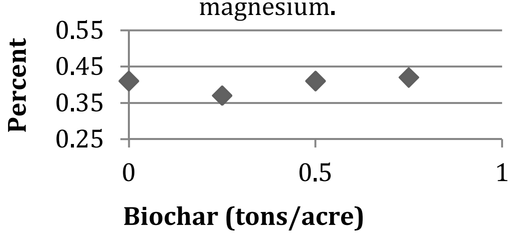


Fig 12.The effect of increasing rates of biochar on plant parts per million iron.

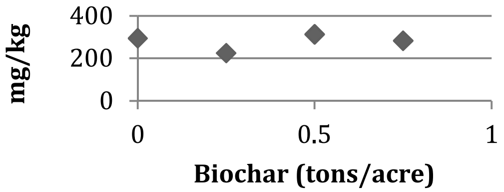


Fig 13.The effect of increasing rates of biochar on plant parts per million copper.

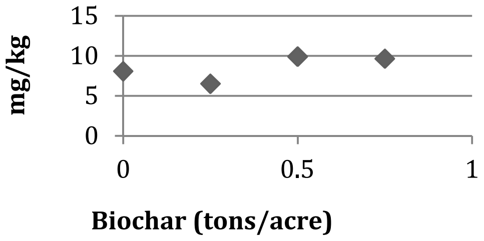


Fig 14.The effect of increasing rates of biochar on plant percent sulfur

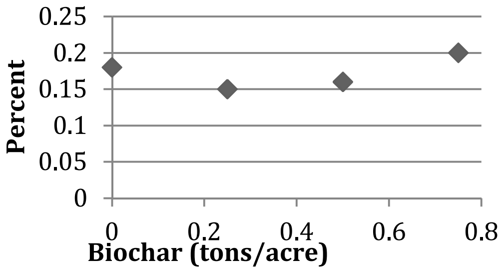


Fig 15.The effect of increasing rates of biochar on plant parts per million aluminum.

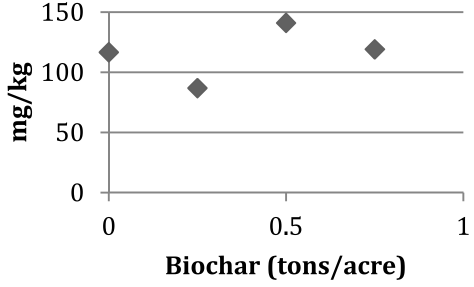
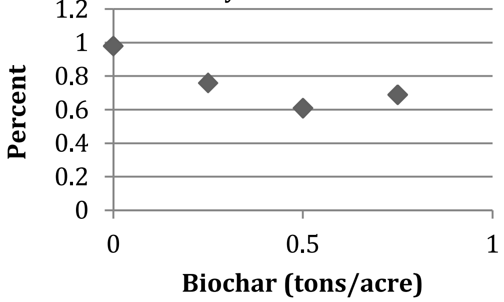


Fig 16.The effect of increasing rates of biochar on plant parts per million molybdenum.



There are several possible reasons to explain why there is no significant difference between rates of biochar for any of the metrics that were measured.

The first possible reason is that the corn was not allowed to grow long enough. If the corn had grow to term, it is possible that differences would have begun to emerge. Also if the corn had been grown to term the ears could have been harvested and total yield calculated. Total yield might have exhibited differences between rates of biochar even if the plants themselves did not. However with the the set up that was used for this experiment the plants were limited by how long they could grow without introducing another variable in the form of transplanting the plants to a larger container.

The second possible reason that no difference was shown between the different rates is that the soil used is fairly healthy and high in nutrients. In a test done by A&L Western Laboratory in 2012 the soil was shown to have nutrient ratings of high to very high almost across the board (Appendix C). One of the benefits of biochar is that it raises pH and increases CEC. However the soil already had a high CEC and was slightly basic before adding biochar. The soil was also high in organic matter, which provides many of the same benefits as biochar. The high organic matter, slightly basic pH and high CEC prior to adding biochar probably was a contributing factor to the lack of significant differences between the rates.

The third possible reason that the different rates had no significant differences between them is that biochar is very stable in the soil (Lehman, 2007). Because of this fact, the eight week growth period may have simply not been long enough for the biochar to start having an effect on the soil.

The final possibility is that biochar just isn't very beneficial for the soil type. Most of the research on the agriculture benefits comes from tropical forests and savannah in South America and South-East Asia (Blackwell et. al. 2009). These soils are almost universally acidic and have a high risk for aluminum toxicity, so the response seen from the application of biochar is often attributed to the alleviation of these problems (Chan and Xu, 2009). As soils on the Central Coast of California, including the soil used for this experiment, rarely suffer from either there was no immediate response in agricultural productivity.

CONCLUSION

The enviromental benefits of adding biochar to soil have been well documented (Blackwell et. al. 2009). However in order for that potential to be realized, applying biochar has to be economical. In an agricultural setting this translates to increasing productivity and yield. The results of this study indicate that the application of biochar does not meet this requirement for growing corn on the Central Coast of California. However there are several potential reasons why the application of biochar did not increase productivity. To accurately determine if biochar does not in fact increase agricultural productivity, the effect of time the plants grow, initial soil fertility, the length of time the biochar is in the soil, and soil type must be explored further.

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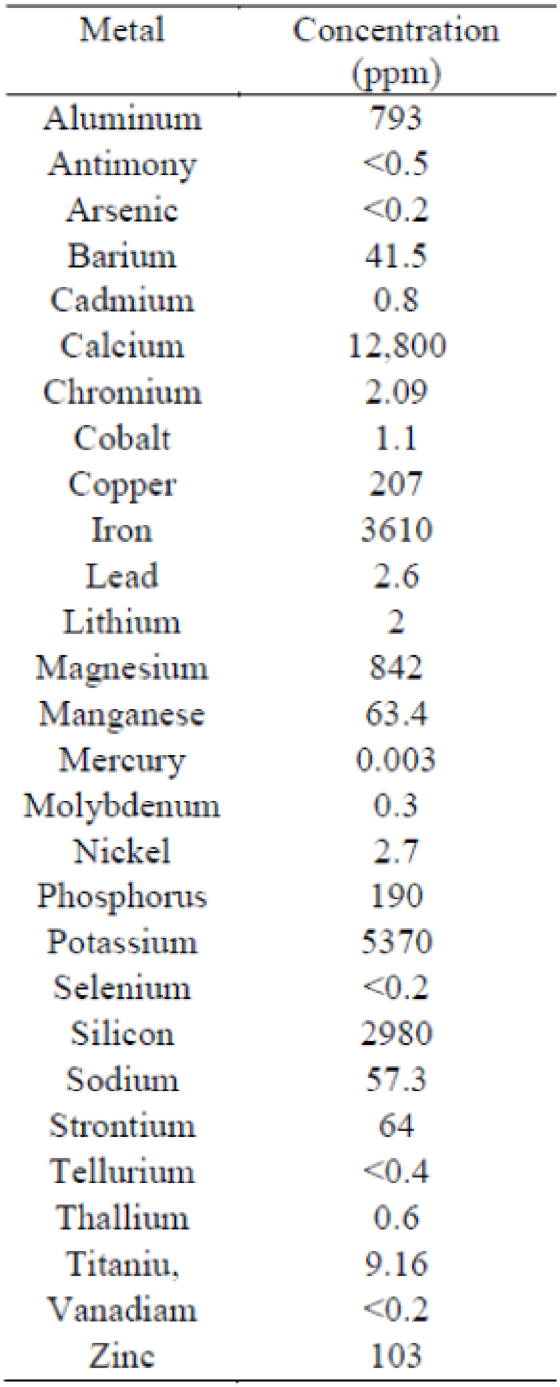
APPENDIX A
METAL CONTENT OF ALTERNA ENERGY, INC. BIOCHAR



Metal	Concentration (ppm)
Aluminum	793
Antimony	<0.5
Arsenic	<0.2
Barium	41.5
Cadmium	0.8
Calcium	12,800
Chromium	2.09
Cobalt	1.1
Copper	207
Iron	3610
Lead	2.6
Lithium	2
Magnesium	842
Manganese	63.4
Mercury	0.003
Molybdenum	0.3
Nickel	2.7
Phosphorus	190
Potassium	5370
Selenium	<0.2
Silicon	2980
Sodium	57.3
Strontium	64
Tellurium	<0.4
Thallium	0.6
Titaniu,	9.16
Vanadiam	<0.2
Zinc	103

APPENDIX B

SALINAS SERIES OFFICIAL SOIL DESCRIPTION

SALINAS SERIES

The Salinas series consists of deep, well drained soils that formed in alluvium weathered from sandstone and shale. Salinas soils re on alluvial plains, fans, and terraces and have slopes of 0 to 9 percent. The mean annual precipitation is about 16 inches and the mean annual air temperature is about 59 degrees F.

TAXONOMIC CLASS: Fine-loamy, mixed, superactive, thermic Pachic Haploxerolls

TYPICAL PEDON: Salinas clay loam, cultivated. (Colors are for dry soil unless otherwise noted. When described, the soil was dry to 5 inches and moist below 5 inches.)

Ap1--0 to 5 inches; very dark gray (10YR 3/1) clay loam, black (10YR 2/1 rubbed) moist; weak coarse subangular ; very hard, firm, very sticky and plastic; common very fine roots; common very fine interstitial, few medium and fine tubular pores; moderately alkaline (pH 8.0); clear smooth boundary. (4 to 6 inches thick)

Ap2--5 to 13 inches; very dark gray (10YR 3/1 moist or dry) clay loam; weak coarse subangular blocky structure; very hard, firm, very sticky plastic; common very fine roots; common very fine interstitial, few medium and fine tubular pores; moderately alkaline (pH 8.0); clear smooth boundary. (7 to 9 inches thick)

A13--13 to 23 inches; very dark gray (10YR 3/1 moist or dry) clay loam; moderate medium subangular blocky structure; very hard, firm, sticky and plastic; few very fine roots; common very fine interstitial and common very fine and few fine tubular pores; some dark grayish brown (10YR 4/2 moist) lumps and mottles, probably due to rodent activity, increasing with depth; moderately alkaline (pH 8.0); gradual wavy boundary. (10 to 12 inches thick)

A14--23 to 33 inches; dark gray (10YR 4/1) loam, dark grayish brown (10YR 3/2) moist; weak medium subangular blocky structure; hard, friable, sticky and plastic; few very fine roots; many very fine interstitial and common very fine and few fine tubular pores; this horizon and all following horizons have about 10 to 14 percent rodent activity with filling of darker A material; moderately alkaline (pH 8.0); diffuse smooth boundary. (8 to 10 inches thick)

C1--33 to 40 inches; grayish brown (2.5Y 5/2) very fine sandy loam, very dark grayish brown (10YR 3/2) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; many very fine interstitial, few medium and fine and common very fine tubular pores; about 5 percent root channels filled with darker A material; slightly effervescent, disseminated lime; moderately alkaline (pH 8.0); gradual smooth boundary. (0 to 10 inches thick)

C2--40 to 49 inches; grayish brown (2.5Y 5/2) very fine sandy loam, olive brown (2.5Y 4/3) moist; massive; soft, very firm, nonsticky and nonplastic; many very fine interstitial, few very fine and fine tubular pores; slightly effervescent, disseminated lime, few fine bodies strongly effervescent; moderately alkaline (pH 8.0); gradual smooth boundary. (8 to 12 inches thick)

C3--49 to 75 inches; light brownish gray (2.5Y 6/2) very fine sandy loam, light olive brown (2.5Y 5/3) moist; massive; soft, friable, slightly sticky and slightly plastic; many very fine interstitial pores; strongly effervescent with disseminated lime; moderately alkaline (pH 8.0).

TYPE LOCATION: Monterey County, California; 1.3 miles south of Chualar underpass on Highway 101; 1,100 feet SW on paved road, 600 feet SE on Farm Road, about 50 feet NE into field.

RANGE IN CHARACTERISTICS: The mean annual soil temperature is 60 degrees to 64 degrees F. and the soil temperature usually is not below 47 degrees F. at any time. The soil between depths of about 5 to 15 inches usually is dry all of the time from about May until late November or early December and usually is moist all the rest of the year. Depth to lime is about 22 to 36 inches. Most of the lime is disseminated, with a few fine to medium lime masses in the lower part. Some pedons have Cca horizons. The soils are neutral to moderately alkaline to a depth of about 22 inches and moderately alkaline below. The 10 to 40 inch control section averages loam, silt loam, clay loam or silty clay loam. It contains 18 to 30 percent clay and more than 15 percent fine sand or coarser.

The A horizon is very dark gray, dark gray or gray (10YR 3/1, 4/1, 5/1) with a chroma of less than 2 to a depth of 22 inches or more. In some pedons, lower A horizons grade to C horizons and are grayish brown (10YR and 2.5Y 5/2). Organic matter content is 1 to 4 percent to a depth of more than 20 inches and decreases regularly to less than 1 percent within 30 inches of the surface.

The C horizon is grayish brown, light brownish gray, pale brown, light yellowish brown or yellowish brown (10YR and 2.5Y 5/2, 6/2, 6/4). It is very fine sandy loam, fine sandy loam, loam, clay loam or silty clay loam, and usually is weakly stratified.

COMPETING SERIES: These are the Agueda, Anaheim, Conejo and Gazos series in the same family and the Linne, Mocho, Pacheco, San Benito, Sorrento and Vina series. Agueda soils are calcareous in all parts and have soft masses of segregated lime within a depth of 40 inches. Anaheim, Linne and Gazos soils have a paralithic contact at depths of 20 to 40 inches. Conejo and Vina soils have a chroma of 2 or 3 in the A horizon and are noncalcareous in the lower part. Mocho and Sorrento soils have mollic epipedons less than 20 inches thick with chroma of 2 or 3. Pacheco soils are seasonally saturated with water within 30 inches of the surface. San Benito soils have a chroma of 2 or more and have a paralithic contact at depths of 40 to 60 inches.

GEOGRAPHIC SETTING: Salinas soils are on alluvial plains, fans, and terraces not subject to current accretions. Slopes are 0 to 9 percent. The soils formed in mixed alluvium mostly from sandstone and shale. They are at elevations of 50 to 2,000 feet. The climate is dry subhumid mesothermal with cool to warm rainless summers with some fog and cool moist winters. Mean annual precipitation is 12 to 20 inches. The average January temperature is 46 degrees to 50 degrees F.; average July temperature is 62 degrees to 73 degrees F.; mean annual temperature is 57 degrees to 60 degrees F. The average frost-free season is 233 to 300 days.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the competing Agueda soils and the Clear Lake, Docas and Metz soils. Clear Lake soils are clay soils with slickensides. Docas soils lack a mollic epipedon and are calcareous throughout. Metz soils are stratified and the control section is sandy.

DRAINAGE AND PERMEABILITY: Well drained; slow to medium runoff; moderately slow permeability.

USE AND VEGETATION: Used mainly for growing irrigated truck, field, and forage crops. Some small valleys used for dry farmed small grain. Noncultivated areas have annual grass and forbs with scattered oak and sycamore in places.

DISTRIBUTION AND EXTENT: Salinas soils are extensive in the valleys of the central and south-central Coast Range of California.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: Davis, California

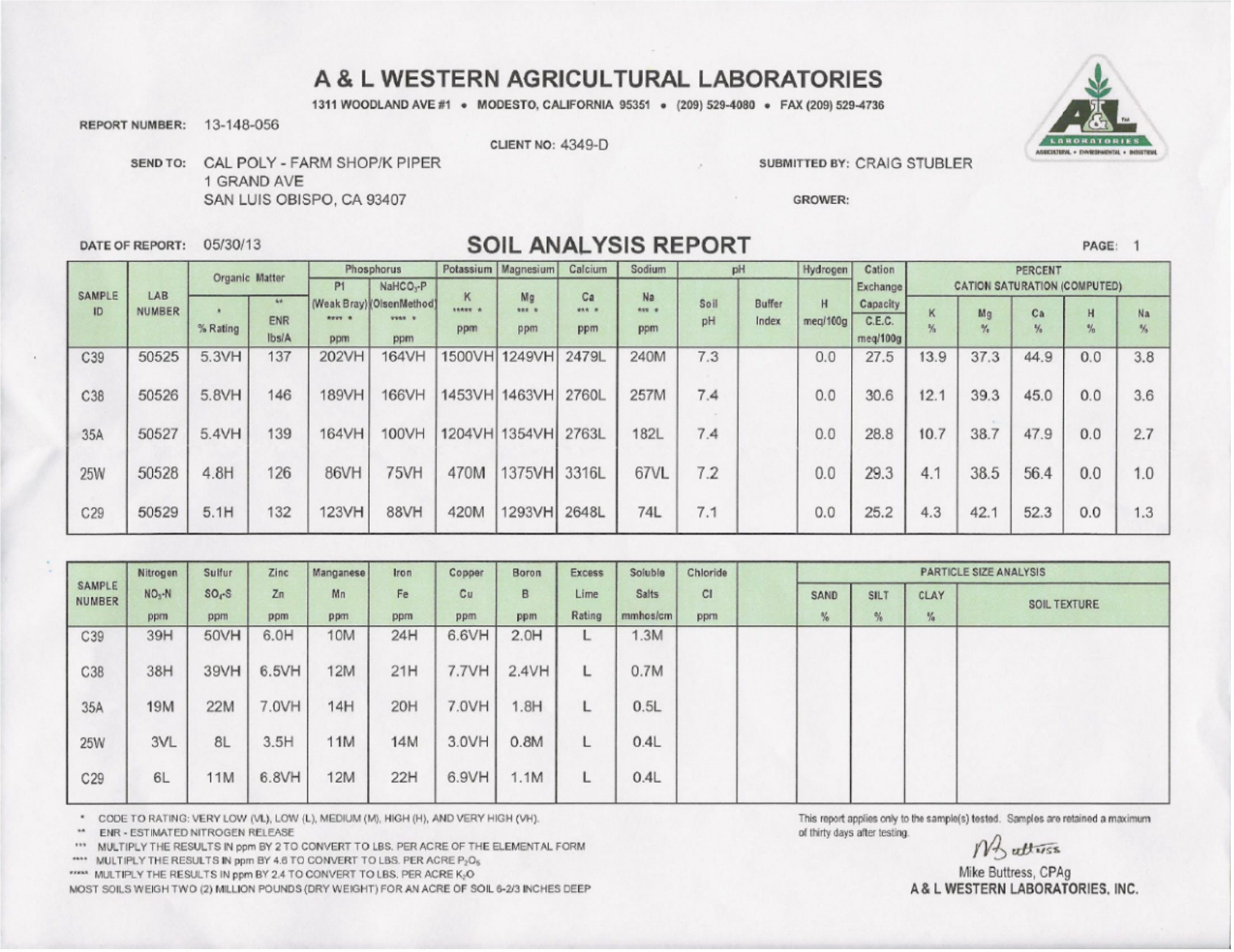
SERIES ESTABLISHED: Monterey County (Lower Salinas Valley), California, 1901.

REMARKS: This is a change in classification from Calcic Pachic Haploxerolls to Pachic Haploxerolls. This site is usually compacted and occurs in a cultivated field subject to long and heavy traffic.

The activity class was added to the classification in February of 2003. Competing series were not checked at that time. - ET

ADDITIONAL DATA: Riverside Laboratory pedon No. S65-Calif-27-11. SSIR No. 24.

APPENDIX C
SOIL ANALYSIS OF CAL POLY FIELD 35A



A & L WESTERN AGRICULTURAL LABORATORIES

1311 WOODLAND AVE #1 • MODESTO, CALIFORNIA 95351 • (209) 529-4080 • FAX (209) 529-4736

REPORT NUMBER: 13-148-056

CLIENT NO: 4349-D

SEND TO: CAL POLY - FARM SHOP/K PIPER
1 GRAND AVE
SAN LUIS OBISPO, CA 93407

SUBMITTED BY: CRAIG STUBLER

GROWER:

DATE OF REPORT: 05/30/13

SOIL ANALYSIS REPORT

PAGE: 1

SAMPLE ID	LAB NUMBER	Organic Matter		Phosphorus		Potassium	Magnesium	Calcium	Sodium	pH		Hydrogen	Cation Exchange Capacity	PERCENT CATION SATURATION (COMPUTED)				
		* % Rating	** ENR lbs/A	P1 (Weak Bray) **** * ppm	NaHCO3-P (OlsenMethod) **** * ppm	K ***** * ppm	Mg *** * ppm	Ca *** * ppm	Na *** * ppm	Soil pH	Buffer Index	H meq/100g	C.E.C. meq/100g	K %	Mg %	Ca %	H %	Na %
C39	50525	5.3VH	137	202VH	164VH	1500VH	1249VH	2479L	240M	7.3		0.0	27.5	13.9	37.3	44.9	0.0	3.8
C38	50526	5.8VH	146	189VH	166VH	1453VH	1463VH	2760L	257M	7.4		0.0	30.6	12.1	39.3	45.0	0.0	3.6
35A	50527	5.4VH	139	164VH	100VH	1204VH	1354VH	2763L	182L	7.4		0.0	28.8	10.7	38.7	47.9	0.0	2.7
25W	50528	4.8H	126	86VH	75VH	470M	1375VH	3316L	67VL	7.2		0.0	29.3	4.1	38.5	56.4	0.0	1.0
C29	50529	5.1H	132	123VH	88VH	420M	1293VH	2648L	74L	7.1		0.0	25.2	4.3	42.1	52.3	0.0	1.3

SAMPLE NUMBER	Nitrogen NO_3-N ppm	Sulfur SO_4-S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Excess Lime Rating	Soluble Salts mmhos/cm	Chloride Cl ppm		PARTICLE SIZE ANALYSIS SAND %	SILT %	CLAY %	SOIL TEXTURE
C39	39H	50VH	6.0H	10M	24H	6.6VH	2.0H	L	1.3M						
C38	38H	39VH	6.5VH	12M	21H	7.7VH	2.4VH	L	0.7M						
35A	19M	22M	7.0VH	14H	20H	7.0VH	1.8H	L	0.5L						
25W	3VL	8L	3.5H	11M	14M	3.0VH	0.8M	L	0.4L						
C29	6L	11M	6.8VH	12M	22H	6.9VH	1.1M	L	0.4L						

* CODE TO RATING: VERY LOW (VL), LOW (L), MEDIUM (M), HIGH (H), AND VERY HIGH (VH).
** ENR - ESTIMATED NITROGEN RELEASE
*** MULTIPLY THE RESULTS IN ppm BY 2 TO CONVERT TO LBS. PER ACRE OF THE ELEMENTAL FORM
**** MULTIPLY THE RESULTS IN ppm BY 4.6 TO CONVERT TO LBS. PER ACRE P_2O_5
***** MULTIPLY THE RESULTS IN ppm BY 2.4 TO CONVERT TO LBS. PER ACRE K_2O
MOST SOILS WEIGH TWO (2) MILLION POUNDS (DRY WEIGHT) FOR AN ACRE OF SOIL 6-2/3 INCHES DEEP

This report applies only to the sample(s) tested. Samples are retained a maximum of thirty days after testing.

M Buttress
Mike Buttress, CPAg
A & L WESTERN LABORATORIES, INC.