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Comparison of Standard Soil Amendments and Calcined Clay on Crop Yields in an Urban Garden at the University of North Carolina Asheville, Asheville, North Carolina

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Abstract

Implementation of amended soils at the Rhoades Property Garden, a campus garden of the University of North Carolina Asheville was investigated for greater land use efficiency and increase of plant growth. Calcined clay are stable soil amendments that improve soil quality through increased cation exchange capacity, increased microbial activity, nutrient retention, and water holding capacity all of which increase plant yield. Two calcined clay amended beds (one constructed the year prior and one newly built) and one standard soil (control) bed were planted with comparable planting schemes of eggplant (*Solanum melongena)*, tomato (*Solanum lycopersicum),* pepper (*Capsicum),* and tomatillo *(Physalis philadelphica*) and received the same amendments, pruning, and watering. Summer harvest yields were calculated for total fruit volume and mass, as well as root mass per bed. Data were analyzed using SAS, ANOVA, paired T-tests and a Tukey post-hoc test. Significant difference in mean eggplant yield as measured by harvest date was found ($p=0.0182$). Comparisons of volume/mass per vegetable and among variety of vegetable were insignificant. The experiment will be extended to test for statistically significant difference in production and to include biochar.

1. Introduction

University campus farms connect students with their community and local food source[1]. However, declining farmland availability requires changes in current agricultural technologies to produce more food per unit of land, while implementing sustainable concepts. Sustainable food production is dependent upon utilizing local resources and sustainable cultivation techniques[2]. As a campus concerned with environmental sustainability, the University of North Carolina Asheville can enrich its community by intensively managing campus gardens using best ecological practices. Such gardens supply produce for various food outlets on campus such as the Wellness Café or the Teaching Kitchen. Developing efficient agricultural techniques will result in improved yields.

The University of North Carolina Asheville's two-acre campus garden at the Rhoades property must be analyzed for potential maximum production. Its pending status depends on responsible and efficient use of the land[3]. The garden's space is not officially designated as permanent student garden, but is in a temporary phase to test its viability as a long-term garden. Not only can ongoing research at the garden enhance the University of North Carolina Asheville's status as a research-focused institution, but it will solidify the Rhoades Property as a garden for future generations of students. The garden will integrate food production, agricultural design, and economic strategy for the University of North Carolina Asheville and the Asheville community.

The University of Montana (UMT) has allotted 72 15' by 15' plots that feature a compost pile, public features including picnic tables and sandboxes, and affordable plot purchases for students and community members[1]. The

University of Virginia (UVA) has a large one-acre plot, the Morven Kitchen Garden, run by UVA students and the Charlottesville community that features a Community Supported Agriculture program from May through October[4]. Both institutions incorporate student independent study projects within a campus garden organization; UVA students are experimenting with growing season extension cost and benefits, edible school yard gardens at the UVA Madison House, and pest and pesticide management associated with beekeeping[4]. The University of Montana's environmental studies program operates a 10-acre farm where students engage in hands on work for credit hours and donate all produce to low income Missoulians[1]. The student-run, 400 square foot Alderman garden plot at UVA provides vegetables to low- income families through the Charlottesville Community Food project as well[5]. Whether engaging in Farm to College (UMT) or implementing rain-water barrels and cover crops (UVA), both schools exhibit a potential model that incorporates sustainable technique and community outreach for the Rhoades Property Garden.

A method to improve local farms and maximize productivity of limited space is the use of calcined clay. Calcined clay is organic, fired, expanded montmorillonite clay often used in turf management to improve soil and increase grass biomass. Similar to ground up brick, its particle size is ideal for consistent soil moisture. Porosity, or the volume of pores over total soil volume, is higher in clay than other textures; pores are sites for soil water containing desirable nutrients for cation exchange[6]. Clay particles and organic matter form soil colloids that lose hydrogen ions resulting in negative charges that results in cation attraction[7]. Cation exchange capacity (CEC) is the maximum amount of cations a soil is capable of holding and is directly linked to levels of nutrient absorption. Calcined clay contains granular aggregates with high pore quantity and a high surface area allowing for increased CEC[8]. Montmorillonite clay is a 2:1 layer silicate clay that consists of one aluminum tetrahedral sheet between two silicon octahedral sheets, where as 1:1 clays consist of a single silicon octahedral sheet and one aluminum tetrahedral sheet in a unit cell[9]. Cations necessary for plant growth through cation exchange are more available in the pelletized 2:1 montmorillonite clay than other high-fired 1:1 clays; they have greater permanent charge due to increased isomorphous substitution in the crystal structure of the clay minerals[6]. Calcined clay reduces phosphorous leaching by 60% and provides calcium (Ca), essential for plant cell wall production[10]. Calcined clay is also high in magnesium that is essential to enzymes in phosphate transfer and chlorophyll molecules[6]. In addition to a high porosity of about 40-50%, calcined clays have a relatively low bulk density of 0.3-0.7g/cm^3 that is ideal to avoid compaction[11]. Calcined clay not only has increased nutrient capacity, but improved drainage compared to peat substrates[8].

Calcined clays also increase water use efficiency. Water use efficiency refers to the moles of CO_2 fixed per moles of water lost by stomata[6]. Compared to a sphagnum peat-perlite root medium, gravimetrically measured water use efficiency was greater by 0.2 and 0.13 mg carbon assimilated/L transpired for calcined clays[12]. Calcined clay increases available dischargeable water that can be absorbed by plant roots[11]. Optimum matrix potentials (1-3 kPa) of calcined clays allows for increased water retention in the plant root zone[8]. Water availability is necessary for nutrient absorption by plants and reduced loss of stomatal conductance. Optimum stomatal conductance allows for higher rates of transpiration and photosynthesis that yield plant growth. Loss of stomatal conductance was calculated through two drought cycles to measure plant response to water stress. After both drought cycles, the control plants grown in 7 peat: 3 perlite mixes had a stomatal conductance of 9 to 18 mmol·m^{-2}·s^{-1} that was two times lower than potted calcined clay media[12]. In treatments that had greater than 40% calcined clay, Bermuda grass experienced significant ($p<0.05$) increased water-holding ability, soil strength, and oxygen diffusion rate[13]. Improved water holding ability is crucial to all turgor. Turgor loss results in plasmosdesmatal collapse and ultimate desiccation[6]. Retention of nutrients and water is beneficial for plants and reduces irrigation needs in a season[10].

Because of its improvement of soil qualities that increase plant productivity, the study examined the effect of calcined clay amendment on food production over the summer growing season (May - August, 2013) and into the fall (September - October 2013). Integration of calcined clay was expected to improve campus garden yield due to its high porosity and increased cation exchange capacity. This will serve as a model for the effects calcined clay on crop growth and a potential mechanism to increase crop yield at the Rhoades Property Garden.

2. Materials and Methods

The study site was UNCA's campus Garden, at the Rhoades Property located on the corner W.T. Weaver and Merrimon Avenue in Asheville, North Carolina. The project focused on three 7.8 m by 0.9 m beds. Bed 1 (the control bed) was tilled by hand with a spading fork to 30 cm. Nine kg of pelletized dolomitic lime was added to each bed. Each bed received 4 lbs of Espoma Organic root-tone[14].The uppermost bed (Bed 4) had been amended with calcined clay the previous year and was located away from the other beds. Bed 4 had greater canopy cover by *Quercus falcata* than the other beds. The site area for the two beds was a 6.1 X 7.8 meter space that was weeded and leveled. Two rectangular beds were measured to 7.8 m by 0.9 m with 90 cm paths between each bed, Bed 1 (the uppermost bed) was determined to be the control (standard amendment) bed and Bed 2 was the calcined clay bed. Bed 2 was excavated to 60 cm. The higher quality of soil (first 30 cm of soil) of the A and B-horizon was kept for incorporation with amendments; subsoil was discarded.

Bed 2 received a soil mixture of 4:2:2 of native topsoil, leaf mulch, and organic calcined clay[15]. Drip-system irrigation was installed with a timer to city water. Planting schemes incorporated similar quantities and varieties for eggplant (*S. melongena)*, tomato (*S. lycopersicum),* pepper (*Capsicum),* and tomatillo *(Physalis philadelphica*) (Table 1). There were uneven varieties of tomato and pepper starts available to plant, but slight difference in variety was seen as less variable than planting from seed. Plants were transplanted into Beds 4, 1, and 2 with 0.6 m per plant. Support was provided for each plant with rebar and Jute twine. Red mulch covered the beds that utilized phytochrome's valuable photoreversible responses induced by plants including stimulated germination and development of leaf primordia and primary leaves (Taiz and Zeiger 2010). The plants were well watered. Standard maintenance included pruning, Neem insecticidal soap and pyrethrin used to manufacture recommendations, and copper oxide for tomatoes.

2.1. Planting Schemes

Table 1. planting scheme in order of appearance (by variety) for Bed 1 (control), 2 (calcined clay), and 4 (calcined clay 1 yr) for tomatillo *(Physalis philadelphica*), tomato (*S. lycopersicum),* pepper (*Capsicum),* and eggplant (*S. melongena)* plants.

Bed 1 (control)	Bed 2 (CC)	Bed 4 (CC 1 yr)
Tomatillo X2	Tomatillo X2	Tomatillo
Tomatillo X2	Tomatillo	Tomatillo
Mt. Magic Tomato	Trust Tomato	New Girl Tomato
Trust Tomato	Juliet Tomato	Granadero Tomato
Juliet Tomato	Juliet Tomato	Juliet Tomato
Trust Tomato	Trust Tomato	Trust Tomato
Roma Tomato	Roma Tomato	Roma Tomato
Granadero Tomato	Trust Tomato	Favorita Tomato
Granadero Tomato	Mt. Magic Tomato	Granadero Tomato
Poblano & Ace Red Pepper	Patamona & Poblano Pepper	Poblano & Ace Red Pepper
Tabasco & Pepperoncini Pepper	Mirasol & Bulgarian Carrot Pepper	Serrano & Pepperoncini Pepper
Eggplant X2	Eggplant X2	Eggplant X2

2.2. Harvest

Once eggplants reached 0.3 m, they were cut at the stem and harvested. Tomatoes, peppers, and tomatillos were collected when they reached maturity and were pulled off the stem. All collected fruits and vegetables were immediately measured using a triple beam balance. The volume was determined with 0.5-L mason jars and 591-mL Tupperware containers. Roots were excised from stems following plant desiccation, soil matter was removed, and dried root mass totals were calculated after one week in a dry oven.

3. Results

Calcined clay incorporation into Bed 2 soil resulted in a significant increase in biomass for *S. melongena* (Table 2, ANOVA T-test; p=0.0182). Calcined clay incorporation soil of the two amended beds resulted in no significant increase of biomass for *S. lycopersicum, Capsicum, Physalis philadelphica* in comparison to a standard amended bed (ANOVA; $p > 0.05$ for all).

3.1. Significance Values Of Crop Replicates

Table 2. significance values among crop replicates for Bed 1, Bed 2, and Bed 4, of eggplant (*S. melongena)*, tomato (*S. lycopersicum),* pepper (*Capsicum),* and tomatillo *(Physalis philadelphica*) mass (g) and volume (mL) per harvest date, crop variety, total bed mass (g) volume (mL) and dried root mass totals (g).

	Analysis variable	Significance (p) value
Eggplant	Mass per Harvest Date	0.0594
	Volume per Harvest Date	0.0837
	Total Mass (Bed 1 and 2) T-test	0.0182
Tomato	Mass per Harvest Date	0.0946
	Volume per Harvest Date	0.2276
	Mass per Variety	0.2037
	Volume per Variety	0.1904
Pepper	Mass per Harvest Date	0.2276
	Volume per Harvest Date	0.2657
	Mass per Variety	0.7744
	Volume per Variety	0.7744
Tomatillo	Mass per Harvest Date	0.3586
	Volume per Harvest Date	0.3870
Bed Total Biomass	Total Mass	0.1741
	Total Volume	0.7080
Dried Root mass	Total Mass	0.6833

3.2. Effect Of Amendment On Total Crop Yield

Amendment use resulted in altered plant yields. Calcined clay addition resulted in significant increase in biomass for *S. melongena* (Figure 3).

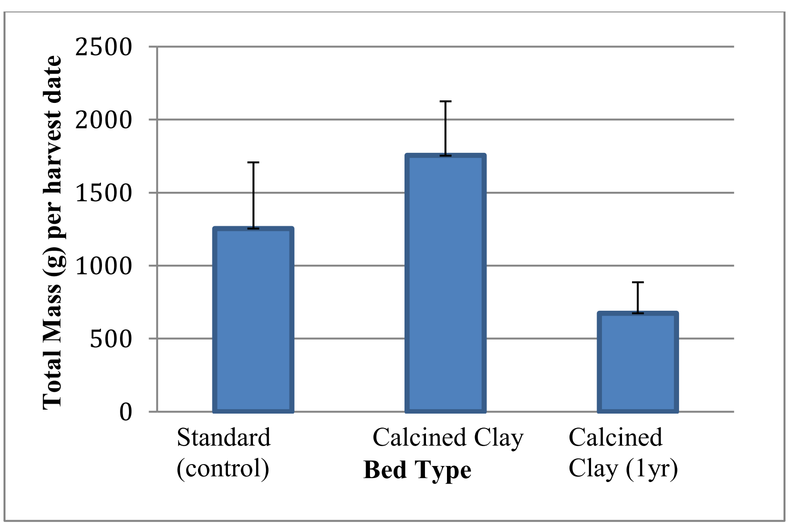

Figure 1. Comparison of total mass of tomato per harvest date.

Figure 1 Mean (±1 S.E.) mass (g) for tomato (*S. lycopersicum*) under three amendment treatments per variety, p = 0.0946.

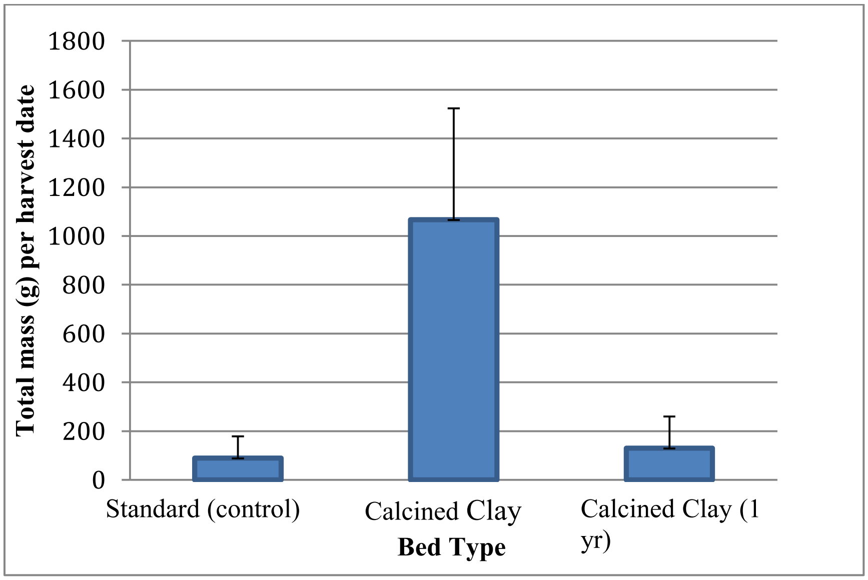

Figure 2. Comparison of total mass of eggplant per harvest date.

Figure 2 Mean (±1 S.E.) mass (g) for eggplant (*S. melongena)* under three amendment treatments per harvest date, p = 0.0594.

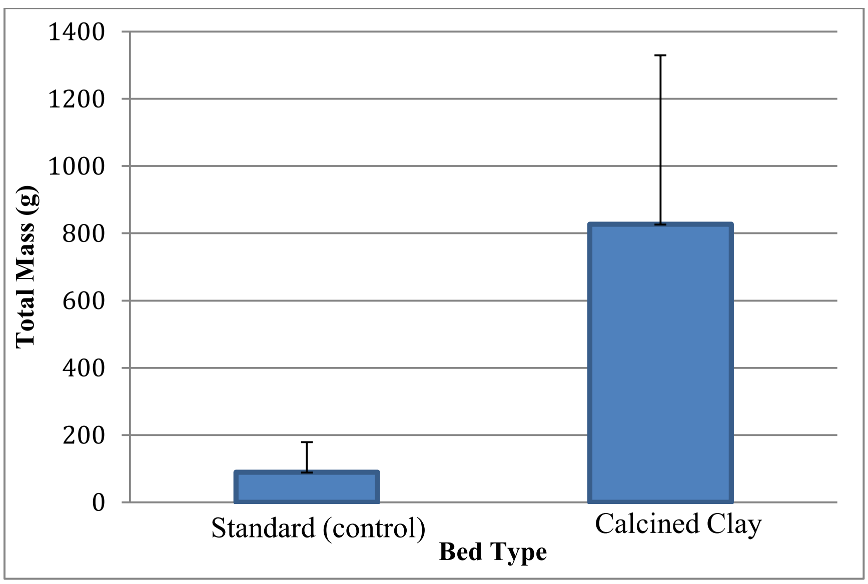

Figure 3. Comparison of total eggplant mass.

Figure 3 Mean (±1 S.E.) mass (g) for eggplant (*S. melongena)* under two amendment treatments per harvest date, p = 0.0182.

4. Discussion

The results of this experiment suggest that calcined clay increases eggplant flowering and growth. Calcined clay has similarly improved soil quality and plant yield in other experiments [12]. Greater root growth was expected in the calcined clay beds, Bed 2 had the highest root biomass in comparison to the standard bed (Bed 1), but no significance was found. Calcined clay was expected to affect all crops, not solely eggplants. Environmental variables disparate among beds potentially affected yield external to soil amendment used. Unlike the near-identical planting of the eggplants, the other crop replicates were dissimilar in their planting due to the restricted number of pepper and tomato starts available for the project. Accessibility and weather damage of tomatillo plants resulted in an uneven quantities of tomatillo plants in the garden beds. There were four tomatillo plants in Bed 1 (the standard bed), but only three in Bed 2 (calcined clay) and only two tomatillo plants in Bed 1 (calcined clay integrated over one year). Thus, quantity of tomatillo plants could have changed overall tomatillo yield for each bed.

Despite equal quantity of pepper plants present in each bed, the varieties planted varied; certain beds featured more of one variety than the other, or varieties not found in other beds. Two tropical pepper plants only planted in Bed 2, (Patamona and Bulgarian Carrot) experienced frost damage and early death, which may have altered total pepper yield. Young Bulgarian Carrot pepper plants develop best and often require a soil temperature above 75°F [16]. All crops necessitated full sun; significant shading over Bed 4 (calcined clay integrated for one year) may have hindered plant growth and overall yields for all crops.

Statistical analysis of the two calcined clay beds and standard amendment bed over the next year(s) will ensure greater validity through consistency of yield improvement and future duration in the soil. Identical planting schemes for replicates potentially involving cover crop will ensure greater statistical accuracy in future experiments. Future biochar implementation is an economically feasible amendment that could be analyzed in comparison to the calcined clay and standard bed yields. In the continuation of soil-amendment experiments with future UNCA students, the Rhoades Property Garden will gain attention as a source of botanical/agriculture related research projects.

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6. References

1. University of Montana, "Greening UM," 2011, http://www.umt.edu/greeningum.

2. Barlett, "Campus Sustainable Food Projects: Critique and Engagement", *American Anthropologist* 113 (2011):101-115.

3. McCarty Holsaple McCarty, "University of North Carolina at Asheville Peripheral Propery," 2008, www.unca.edu/sites/default/files/Campus_Master_Plan/UNCA_Peripheral_Property_Study_1.pdf.

4. University of Virginia Foundation, "Morven Kitchen Garden," 2013, www. uvafoundation.com.

5. M. Kelly, "Learning and Growing: Garden as Laboratory at U.Va," *UVA Today* (2009), http://news.virginia.edu/content/learning-and-growing-garden-laboratory-uva.

6. M. Singer and D. Munns, *Soils: An Introduction* (Upper Saddle River: Prentice Hall, 2005).

7. L. Taiz and E. Zeiger, *Plant Physiology (*Sunderland: Sinauer Associates Inc., 2010).

8. H. Jeon, G.S. Lee, B.G. Kim, and C.L. Park, "Modification of Calcined Clay and Its Physical Properties for Use as a Subsidiary Material For Growing Media," *Journal of Plant Nutrition* 33 (2010): 654–669.

9. Foth H, *Fundamentals of Soil Science* (New York John Wiley & Sons, 1990).

10. Clemson Cooperative Extension, "Alternative Substrates," 2014, www.clemson.edu.

11. H. Jeon, G.S. Lee, J. Lee, B.G. Kim, and C.L. Park, "Improved Calcined Clay with a Spherical Layered Structure and its Characteristics as a Medium for Plant Growth," *Applied Clay Science* 49 (2010): 298-305.

12. R. Ogutu, K. Williams, and M. Kirkham, "Calcined Clays and Diatomaceous Earth Used as Components of Soilless Root Media Influence Water Retention, Availability, and Water Use Efficiency During Production and Post-production of Impatiens," *Hortscience* 43 (2008): 1175.

13. G. Wehtje, J. Shaw, R. Walker, and W. Walker, "Bermudagrass Growth in Soil Supplemented with Inorganic Amendments," *HortScience* 38 (2003): 612-617.

14. Espoma, "Organic Fertilizers & Pesticides for Lawns & Gardens," 2012, www.espoma.com.

15. Pro's Choice Select, Soil Conditioners 101," 2008, www.Proschoice1.com/about.html.

16. Sustainable Seed Company, "Bulgarian Carrot Pepper Seeds," 2014, www.sustainableseedco.com.