EFFECTIVENESS OF AMENDMENTS AND MICROBIAL TREATMENTS ON PLANT GROWTH IN URBAN GARDEN SOILS

BY

KEVIN SUMMERVILLE

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EFFECTIVENESS OF AMENDMENTS AND MICROBIAL TREATMENTS ON PLANT GROWTH IN URBAN GARDEN SOILS

Kevin Summerville

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Signature:

Kevin Summerville Student Date

Approvals:

Felicia Armstrong, Thesis Advisor Date

Dawna Cerney, Committee Member Date

Colleen McLean, Committee Member Date

Rich Ciotola , Committee Member Date

Dr. Salvatore A. Sanders, Dean of Graduate Studies Date

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Chapter 1 Introduction

Cities and urban areas constantly go through periods of growth and recession; often these oscillations are on a small scale and in a fairly balanced manner. When thriving areas suffer economic hardship and experience rapid or sustained job loss urban areas are often left with abandoned industry, housing and buildings which turn to blight and further worsens a bad situation. This is a situation which happened in the City of Youngstown, Ohio starting in the late 1960's, when the thriving steel industry slowed and eventually all but ceased. (Posey 2013).

With the steady decline of Youngstown's main industry, the city turned from a once thriving considerably wealthy middle class area to a poverty stricken city with an ever declining population. Today a large portion of the residents of Youngstown, Ohio live below the federal poverty line, earning less than $24,000 a year for a family of four (Murthy 2016) . Many of the areas within the city where these residents live also have a high percentage ~25% of vacant buildings and lots (CityData 2013). These factors coupled with the city's ongoing plan to remove abandoned buildings and houses, (blight) is creating vacant parcels of land.

The decades of economic decline have also resulted in many of the residents lacking accessibility to nutritional food as there are not any grocery stores, farmers' markets, or healthy food providers within an accessible distance or at costs that a large portion of the population can afford on a regular basis. For these reasons the USDA classifies the city of Youngstown as a food desert. Food deserts are areas void of access to nutritional food; fresh produce or healthy whole foods for reasons of availability, affordability, or limited access for reasons of distance or lack of transportation (USDA

2016). These devoid areas known as food deserts occur most typically in cities and localities where urban sprawl is significant and poverty levels of the population are elevated. (Mead 2008). All these factors combined have created problems no doubt but an opportunity for residents as well. The vacant space that communities can take advantage of to establish urban gardens and obtain nutritional food for at least part of the year which they would otherwise lack (Mahoning Land Bank, 2017).

One of many tools to combat against food deserts is the establishment of urban gardens and urban farms. The installation of urban gardens can provide communities in food deserts access to fresh, nutritional, locally grown food. This is something that many residents may not have the means to afford or conveniently access otherwise. Urban gardens are beneficial to communities for their role in providing communities a platform to work together, save money, eat healthier and act as a learning mechanism (Vitiello et al 2014).

Often, blighted areas, where buildings once stood, have poor soil quality that is not ideally suited for growing gardens. The parcels often have soil of poor physical and chemical quality due to the overall composition, compaction and lack of nutrients available for the plants. The poor soil quality is due to the initial development of the site which involves the process of excavating the topsoil prior to building. Additionally if the site is developed for industry, soil compaction can become a major issue as a result of large industrial buildings and the use of heavy equipment compacting the soil throughout the life of the site (Craul 1999). Without addressing the issue of soil quality, the time and effort put forth during the growing season can be met with poor crop yields.

Unsatisfactory yields can discourage residents from continuing the practice of urban gardening in future seasons.

Many urban gardens have been established in Youngstown primarily as raised bed gardens and although this is a method which can fix the issue of soil quality it might not always be the best or most cost effective approach. As more communities establish gardens in urban settings and interest in the practice gains momentum it is important to evaluate different options and compare each against the other for cost effectiveness, efficiency, and environmental impacts. In addition, it is important to provide multiple options as no one solution will be a perfect fit to address the conditions of depleted soil quality in all instances at all times.

A wide variety of amendments have been used in past studies to improve poor soil quality in urban locations. These amendments focus on improving the urban soil's physical, chemical, and biological properties. The effects that amendments will have on soil quality depends on a variety of factors. The type of amendment chosen, the amount, and method of application will lead to varying final results in physical, chemical and biological parameters. Not only will the amendment and parameters associated with the amendment matter but the initial state of the soil and its various parameters must be kept in consideration. Various types of compost have shown to be capable amendments to improve soil quality in physical, chemical and biological activity (USCC 2001).

Compost has been shown to improve the soil quality from a physical standpoint by increasing the available water capacity (AWC), increasing the total C and organic matter (Beniston et al. 2014). Compost also improves the soils chemical quality since it is nutrient rich material. Compost contains compounds that are mainly organic forms of nutritional compounds that the plants can use over an extended period of time. In addition to containing such compounds, compost can increase nutrition is by increasing the soil electrical conductivity (EC). This provides additional sites on the soil surface where ionic compounds can adsorb and lay readily available for plants to absorb. Compost has been shown to increase the three primary nutrients (N, P, K) especially when derived from at least in some part manure (De Lucia et al. 2013).

The City of Youngstown had contacted Youngstown State University regarding a vacant lot of land in the Oakhill community, located west of downtown Youngstown. They requested an analysis of the soil conditions of the lot be conducted so the community could use the parcel for a community garden. Efforts by the City of Youngstown, the Land-bank, and neighborhood partnership groups removed many of the houses leaving the lots clear of structures. Many of these lots were used for playgrounds, green space, basketball courts, and raised bed gardens. The City would like to see the expansion of urban gardens to not only provide fresh produce to the neighborhood but also provide a source of income for the residents. This study focused on using various soil amendments on soil from Oakhill vacant parcels to improve soil quality and increase plant growth for the establishment of an urban garden.

Chapter 2 Literature Review

Background of Youngstown

Youngstown, Ohio was once known as the Steel Valley. During its most prosperous decades, the 1930's through the 1950's Youngstown had a population of around 170,000 and a viable steel industry serving as the economic motor of the city. The steel industry started to decline in the 1960's with the most devastating blow coming to the industry on the 19th day of September in 1977 when the Campbell Works closed. Many see that day as the beginning of the end of the steel industry in the valley. Between 1976 and 1986 additional steel mills closed or reduced production output and laid off workers and 40,000 jobs were lost during that time period (High 2002).

Throughout the decline of the steel industry and after there have always been attempts to revitalize Youngstown whether it be by bringing steel back or trying to generate new industry and take the city in a new direction. Towards the later part of the 90’s and early 2000’ Youngstown established the Youngstown 2010 plan. The plan established a plan to repurpose land to try and create industry and generate new business. There has been some success with the establishment of new businesses but nothing has been able to drive an increase in population. As of June 1, 2016, the estimated population of the Youngstown metropolitan area is 547,700, an average decline of 2,900, or 0.5 percent, annually since 2010 (HUDuser.gov 2017).

Another goal of the 2010 plan was and is to deal with the blight across the city from industries of the past. Through federal grant money the city is removing this blight and creating a more aesthetically pleasing appearance in an attempt to improve the city. The Land Bank was awarded a $4.27 million for the Neighborhood Initiative Program (NIP). This is a demolition grant awarded in early 2014 funded by the Ohio Housing Financing Agency. An additional $500,000 performance-based bonus was granted in November 2015. Additional performance-based awards of $6.89 million in July 2016 and $3.15 million in October 2016 will fund demolition activities through mid-2019 (Mahoning Land Bank, 2017).

Nutrients and Soil Properties

There are fourteen elements which are considered to be essential for plant growth that are obtained primarily from the soil. There are additional elements which are also considered essential (carbon, hydrogen, and oxygen) but are obtained through atmospheric interactions and several other elements (cobalt, selenium, silicon, sodium and vanadium) which are considered beneficial but not essential. Essential elements are needed by the plant to complete its normal life cycle and without the elements, the plant would be adversely effected. The essential elements are more commonly known as nutrients and are divided into two groups, macro and micro nutrients based on the amount plants require.

Elements that make up the macro nutrients are nitrogen, phosphorous, potassium, calcium, magnesium and sulfur. Micro nutrients are boron, chlorine, copper, iron, manganese, molybdenum, nickel and zinc (Barker et al. 2007). Optimal yields can only be produced when all these nutrients are in proper supply. According to the Law of Minimum, if one or more nutrients are lacking in the soil, crop yields will be reduced, even though an adequate amount of other elements are available (Barker et al. 2007).

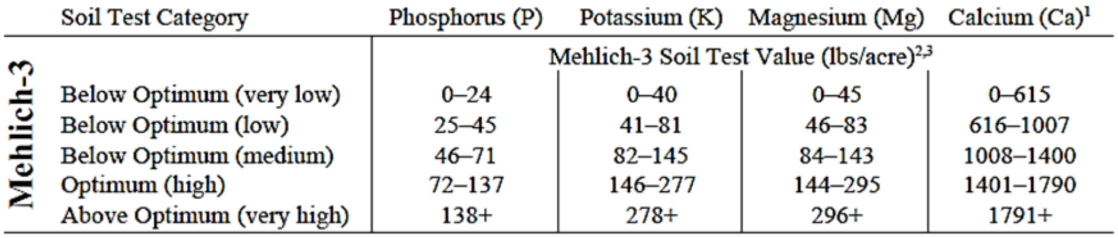
The macronutrients are further broken down into two additional categories, primary and secondary. The “N, P, K” ratio seen on fertilizer bags are three of the six macro nutrients and commonly referred to as the primary nutrients. They are essential for plant growth and play many key roles throughout the plants growth and development. Nitrogen is required to form amino acids and thus proteins and carbohydrates, needed for cell division to occur, and plays an essential role in photosynthesis (Graham et al. 2006).

The amount of nitrogen in a soil can be measured in several ways. Nitrogen testing can be conducted to determine the total amount, which is less common. Testing can be conducted for mineralized nitrogen, which is the plant available forms, which is more common. The two main inorganic forms that plants can uptake most readily are ammonium (NH_4^+) and nitrate (NO_3^-) and are analyzed to determine if nitrogen should be added to the soil. Typical concentrations of nitrate and ammonium considered to be sufficient for the majority of crops are 25-30 mg/kg and 2-10 mg/kg respectively. Nitrate can be further divided into low, moderate, high and excessive. For most crop requirements nitrate would be low at < 10 mg/kg, moderate 10-20 mg/kg and high 20-30 mg/kg and excessive > 30 mg/kg (Marx et al. 1999).

Phosphorous is involved in photosynthesis, respiration, energy storage, cell division and growth. Phosphorous also encourages early root formation, helps develop the fruit and reproductive bodies of plants including seed formation and encourages the growth and resiliency of the plant. Potassium is necessary for metabolizing carbohydrates and starches, increases the rate of photosynthesis and plays a key role in plant water-use efficiency. Additionally it is involved with controlling reaction rates, synthesizing proteins and aids the plant by improving resiliency to diseases and cold (Sanchez 2006).

Like nitrogen, levels of phosphorous and potassium are also very commonly tested for as they are required in large quantities relative to other nutrients and can often be deficient in soils and need to be monitored. These nutrients can become limiting when available levels get too low and can result in crop stress and lead to lower yields. Nutrient ranges for phosphorous, potassium, magnesium and calcium are listed in Table 1 below. The table shows the very low and low ranges of each nutrient where deficient levels could reduce relative yields. On the other end of the spectrum when concentrations get above optimum in the very high range, nutrient toxicity can occur which can also negatively impact crops and result in reduced relative yields (Heckman et al, 2000).

Table 1 Ranges for Macronutrients extracted using Mehlich III (Heckman et al, 2000).



	Soil Test Category	Phosphorus (P)	Potassium (K)	Magnesium (Mg)	Calcium (Ca)[1]
		Mehlich-3 Soil Test Value (lbs/acre)[2,3]			
Mehlich-3	Below Optimum (very low)	0–24	0–40	0–45	0–615
	Below Optimum (low)	25–45	41–81	46–83	616–1007
	Below Optimum (medium)	46–71	82–145	84–143	1008–1400
	Optimum (high)	72–137	146–277	144–295	1401–1790
	Above Optimum (very high)	138+	278+	296+	1791+

In addition to defining ranges for the primary macronutrients as well as secondary and micronutrients soil properties; pH, organic matter and texture, mainly can alter nutrient availability and plant growth and must be considered (Brady and Weil 2002). Soil pH is very important to nutrient availability and greatly controls which ones will be accessible to plants and in what quantity. Changes in pH can greatly alter nutrient availability and dictate what the plant will able to uptake (Figure 1).

The pH of soils can vary significantly and several things should be taken into consideration. From a larger scale perspective consideration towards geographical and industrial derived influences should be given. Two of the major influences specific to geographical location are climate and the parent material’s chemical makeup and can affect the pH over spatial ranges. If there are industrial influences either past or present where wet and or dry deposition is a factor, soil pH can be altered, typically creating more acidic soil conditions.

Natural factors, on large or small scales can affect soil pH and are the combined effects of soil-forming factors; parent material, time, slope or topography, climate, and organisms, which results in a soil with specific mineral content and soil texture. The pH of newly formed soils is highly influenced by the minerals in the parent material of the soil (USDA 2004). In northeast Ohio (Region 6) the typical soil is the Mahoning-Rittman-Canfield-Chili, and tends to have slightly acidic to neutral soils with pH ranging between 6.2 –7.0. This pH range is suitable for plant growth since the majority of crops grow optimally in a pH range of 6.2–7.3 (Figure 1). If the balance of pH becomes too acidic, below 6.0; the plants suffer from macro nutrient deficiencies. On the other end of the scale when soil becomes too alkaline, above 7.5 (USDA 2012); several of the micro nutrients are locked in organic forms making them unavailable to plants (Brady and Weil 2002).

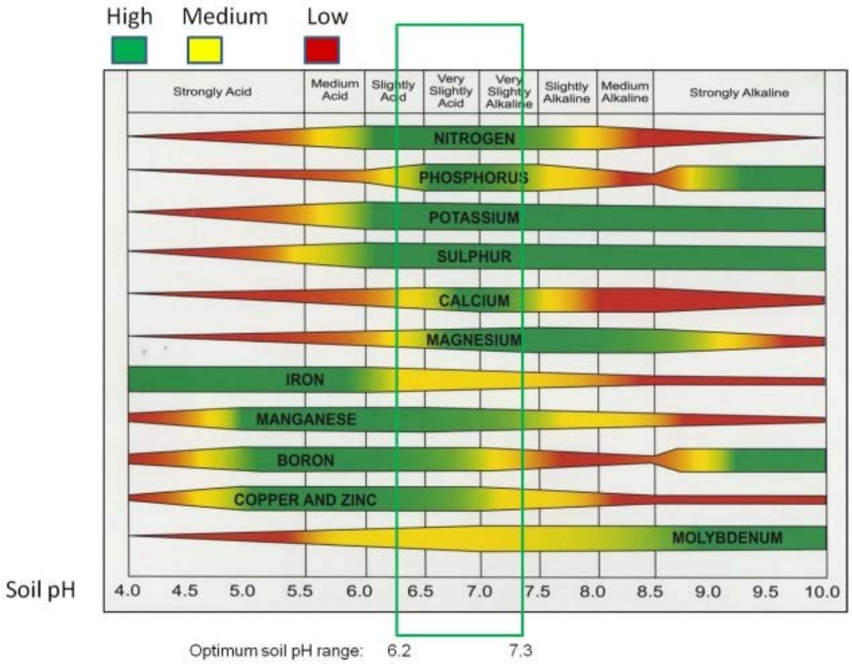


Figure 1 Effect of pH on Nutrient availability in soil (Heartland Outdoors 2015).

Just as soil pH can greatly influence crops access to nutrients the amount of organic matter present in soil can influence nutrient cycling between soil and plants via its contribution in cation-exchange capacity (CEC). Soil organic matter is a mixture of all compounds of the soil which contain carbon. Organic matter is an intricate and diverse mixture of substances; that includes fresh residues, living organisms, decomposing organic compounds and stable organic compounds (humus) (USDA 2001). Organic matter is a dynamic variable in soil and a major influence on many chemical, physical and biological properties (Brady and Weil 2002). Organic matter is constantly changing and degrading into finer organic fractions as it decomposes. The fraction of organic matter in non-cultivated soil typically ranges between 3-10% of the total dry weight.

The amount of organic matter can affect many other properties of the soil. Organic matter is most influential in CEC, water holding capacities as soil stabilization due to its aggregate properties. Organic matter can acts as a water buffering media by increasing water retention and infiltration rates. The structure and aggregation of the organic matter can increase atmospheric diffusion into the soil. Organic matter can alter the CEC and or the rate of adsorption and deactivation of agricultural chemicals especially when a greater portion of the organic matter is humus.

Soils with higher levels of organic matter tend to have higher nutrient content, typically in non-mineralized forms. Although a large portion of these compounds are not in forms readily available to the plants they can act as a nutrient storage pool that plants can utilize. Depending on various soil parameters these nutrient storages will be slowly transformed to mineralized forms and become readily available to plants over a longer period of time. Organic matter also influence soil color. With increased levels of organic matter the soil typically has darker shades of brown or black. The color of soil can affect soil temperature; darker soils will have higher temperatures which can be beneficial to the organisms and hasten processes including chemical reactions, water uptake and biological growth and decay (Schnitzer 1982).

Soil texture is the ratio of different sizes of inorganic particles in the soil. The size, distribution and relative abundance of individual soil particles determines the texture and physical composition of the soil. The three particles that soil consists of are sand, silt and clay. Sand consists of the largest particles that range from <2000 to 50 µm, while clays are the smallest particles consisting of any particle <2 µm and silts fall between these two sizes and have a range of <50 to >2 µm. Soils with a larger proportion of sands than silts and clays will have a higher rate of water/air infiltration.

Soils with higher fractions of smaller silt and clay particles will have lower permeability and porosity than a soil with higher clay and silt (Gee and Bauder 1986). Soils with high percentages of sand have low water-holding capacities, good aeration, high drainage rates, and lower levels of organic matter as compared to soils with high amounts of clay and have high water holding capacities, poor aeration, slow drainage rates and medium to high organic matter content.

The soil texture is based upon this composition of particles separated into these size categories. The role that soil particle composition of the soil plays on CEC is significant. Soils with higher levels of clay particles will have a greater efficacy for CEC as clay particles have larger surface areas and are negatively charged particles which cations can attach themselves too. Since many cation compounds are in mineralized forms soils with higher CECs can provide a nutrient pool for plants to pull from (Olorunfemi et al. 2016).

Soil amendments have been shown to improve soil physical and chemical parameters. Composted sewage sludge (SSC) was used to amend soil to increased moisture and infiltration values of the soil. The SSC was applied at rate of 0 to 45% by volume. The plant species *Myrthus* and *Rhamnus* had improved growth at 15, 30 and 45% with the optimal growth being seen at 30%. The hedge species *Phillyrea* showed 30 and 45% application rates yielded the best results. (Delucia et al. 2013).

Another study over a two year period showed that application of large quantities of compost produced from urban waste can improve soil properties and increase crop yields. The site location used had previously been a residential lot and the use of heavy machinery during demolition and grading had a negative impact on the soil quality to do compaction (Beniston et al. 2014). The addition of compost showed improved bulk density an increase in C, P, K, Ca, Mg and S over the control and most importantly a significant in all three crops grown; tomato, swiss chard and sweet potato crops.

Plant growth promoting bacteria have been effectively used to increase yields of cotton crops. Several plant symbiotic bacteria; *P. denitrificans PsD6*, *B. amyloliquifaciens BcA27*, *M. phlei MbP18*, *A. globiformis ArG1* and *A simplex* significantly increased the shoot cotton crop biomass by 13 – 38% over the control at the 0.05 significance level (Egamberdiyeva et al. 2003). Many strains of *Bacillus* are categorized as P-solubilizing due to their ability to alter organic forms of phosphorous into mineralized molecules increasing available P for plant uptake. Inoculation of two strains, *Bacillus M-13* and *RC01* increased phosphorous availability by 16.9% and 8% for barley seed crop compared to the control (Canbolat et al. 2005). *Bacillus RC01*, *RC02*, *RC03* and *M-13* all increased NO_3 and total mineral N of the soil significantly over the control. Total barley dry weight increased with all bacterial inoculations but no strain increased the total dry weight at a significant level over the control.

Arbuscular mycorrhizal fungus (AMF) have shown to be beneficial to their plant cohosts through several mechanisms. They can enhance nutrient obtainability and increase uptake, function as biological protectants against pathogens, alleviate soil stresses and produce more favorable and sustainable conditions for plants (Siddiqui et al. 2008).

Inoculation with AMF species in a three year field study demonstrated positive responses in several types of horticultural plants; melon, green pepper and eggplant and mycotrophic leguminous field crops, horsebean, chickpea and soybean by improving plant health or crop yields compared to non-inoculated group (Ortas 2011). The inoculated plants generally demonstrated increases in P and Zn uptake but no correlation between uptake in these nutrients and an increase in yields. Additionally AMF inoculation coupled with other biofertilizers rather than a standalone management system has demonstrated better results.

Microbial Soil-Plant Environment

The microbial soil community that inhabits soils is vastly extensive and diverse. These microbial communities are influenced by many factors including temporally, spatially and climate driven influences. The soil specific physical, chemical and biological properties will further determine establishment of microbial communities. The predominant microbes found in soils are heterotrophic making their survival dependent on the energy sources available in the soil. The amount and type of inorganic and organic, both dead and living forms of energy sources greatly influences which microbes will flourish and sustain. The main categories which soil microbes reside under are bacteria, fungi, actinomycetes, nematodes and protozoan. (Manoharachary and Mukerji 2006).

The roles of these various organisms can be saprophytic and varying degrees of symbiotic ranging from parasitic to mutualistic. Microbial distribution is wildly heterogeneous and vary greatly in a few inches of space especially between the rhizosphere and non-rhizosphere constraints (Manoharachary and Mukerji 2006). The soil microbiology affect the soil-plant environment around the plant roots or rhizosphere. The microorganisms can make nutrients more available by decomposing organic matter or fixing nitrogen to a form plants can utilize. There are a wide variety or microorganisms that can improve soil nutrient availability, the AMF and bacteria associated with the rhizosphere have shown beneficial effects on species of Fabaceae, Poaceae, and Cruciferae.

The most well know role of arbuscular mycorrhizae fungi plays is expanding plant root access beyond the plants typical rhizosphere by creating a more extensive network for the plant to access nutrients. AMF and rhizobacteria can also stimulate the growth of plants by mobilizing nutrients that would otherwise be locked up in forms inaccessible to plants and through production of phytoeffective metabolites. The phytoeffective metabolites aid in protecting plants from pathogens, decomposing toxic substances and increasing the stress tolerance, and by forming stabile soil structures (Hoflich et al. 1994).

The microbial community around and in the plant rooting systems is influenced by the exudates, lysates and mucilages from the roots in conjunction with other soil and conditional qualities (Hoflich et al. 1994). The exudates, lysates and mucilages are also dependent upon plant species. The available organic compounds found in the soil will also act as a determining factor and alter the heterotrophy of rhizosphere organisms.

These factors however and their influence on crops and the ability to control the wild microbial population living in the soil can, for the most part, is an unattainable goal, because the soil contains a plethora of microorganisms. Some of the microorganisms are deleterious in nature interact in a parasitic symbiotic manner, while others can effectively function as plant growth-promoting organisms. All rhizosphere organisms use the plant roots and the associated organic deposits as a source of energy for their own growth and development. The rhizosphere microorganism community is for the most part in a state of balance. However during the early stage of root development it is possible to influence this balance, by selective inoculation to encourage the growth and development of plant growth promoting or beneficial microorganisms in the rhizosphere (Hoflich et al. 1994).

Inoculation of seedlings prior to planting and in the early stages of root development with desired strains of AMF and rhizobacteria could provide significantly better growth of beneficial symbiotic microbes. The effectiveness of these beneficial microorganisms can be based upon their metabolic features and the effectiveness they ultimately have on plant growth. Some of the major criteria which these microbes must address is 1) The ability to mobilize nutrients such as various phosphates and their ability to fix atmospheric nitrogen. 2) The ability to stimulate nutrient uptake to the plant 3) Offer some protection against soil-borne plant pathogens and keep deleterious bacteria restrained (Hoflich et al. 1994).

Compost Amendments

If the cost of fertilizer continues to rise with the continued adverse environmental impacts from excessive fertilizer addition, other forms of more sustainable amendments are needed for the urban farmer. Amendments such as compost, provide a variety of benefits including the enhancement, formation and functioning of AMF. Compost consist of organic residue most commonly from plant waste, leaves, grass clipping or similar material.

The residue is ‘composted’ through a process of piling and allowing the residue to heat throughout the breakdown process as microbial populations increase. The feedstock. pH, percent moisture and aeration of the pile should be monitored to maintain an efficient process. The most prevailing challenge when using organic amendments is ensuring they provide a reliable and predictable supply of nutrients (Quailty and Cattle 2011, Rose et al. 2014).

Unlike inorganic nutrients, where a precise amount can be applied to soil and a relatively accurate plant response predicted, organic amendments tend to be less predictable because of the nutrient release rate varies. This is due to the extra chemical step of converting organic nutrients to mineralized nutrients before they can be taken up by plants (Jackson et al. 2008, Paul 2006). The role that arbuscular mycorrhizae play in nutrient availability and the effects that compost applications could have upon the arbuscular mycorrhizae community have many dynamics to be evaluated. The availability of nitrogen, carbon and phosphorus may influence the type of interaction the AMF will have with the plants (Kapoor and Mukerji et al. 2005). The relationship could prove just as significant as the mineralization of nutrients from organic compost. This could provide additional flexibility for use of organic fertilizers by altering or promoting the mycorrhizae community with inoculation or other means to increase the nutrient mineralization and thus plant uptake.

Hyphosphere (root free with hyphae)

The benefits of using compost as a fertilizer and soil conditioner to improve physical, chemical and biological soil properties has been well documented over many decades. Adding compost to soil can physically improve it by altering the texture. The compost can enhance the physical structure of soil. In fine-textured soils, the addition of compost will reduce bulk density, produce a more workable soil structure and improve porosity. The improved porosity will increase its gas and water permeability which reduces erosion. Compost when used in sufficient quantities has an immediate as well as a long-term positive impact on soil structure. Compost typically consists of larger aggregates and resists compaction in fine textured soils. In coarse-textured (sandy) soils water holding capacity improves along with soil aggregation (USCC Fact Sheet, 2008).

The addition of compost can also be beneficial to plants by introducing nutrients to the soil which is a chemical benefit. One of the chemical parameters which the compost can alter is the pH of the soil. Compost will effectively incorporate macro and micro nutrients into the soil often times in organic non mineral forms. The organic nutrient compounds are beneficial to plant nutrition over longer periods of time then non-organic forms are. The nutrients will be released to plants much slower and last for longer durations without the need of additional fertilizer input.

In addition compost can improve the cation exchange capacity (CEC). Since compost tends to be high in organic matter content which is composed of both positively charged and negatively charged compounds it tends to increase the CEC of soil. (Rhoades 1982). A simplified explanation of CEC is how many negatively charged sites are available for positively charged ions or cations to bind to. This is important since several of the macro and micro nutrients required for plant growth and health are available to plants in their mineral ionic form as cations. Three very important nutrients available as cations are potassium, calcium and magnesium. The greater amount of adsorption sites found in the soil allows for greater nutrient retention ability.

In terms of biological benefits compost can increase soil biota and biological diversity and activity which has the ability to positively promote plant health. The major constituents of soil microorganisms include bacteria, protozoa, actinomycetes, and fungi. These microorganisms tend to proliferate when a higher content of organic matter is present, which compost is rich in. These microorganisms play a very important role in the cyclic process of organic matter decomposition through their energy obtaining life processes which transform organic compounds into mineral plant available nutrients. Certain microbes can encourage root activity in several ways. In particular the microbes may create areas throughout the non-homogenous soil of plant available nutrient rich pockets that will lead to root probing and ultimately expansion.

Certain microbes can also form synergistic or mutualistic symbiotic relationships with the plant roots. A prime example of this are the multiple types of mycorrhizae fungi which grow intracellularly with the plant root as arbuscular mycorrhizal fungi, or extracellularly as in ectomycorrhizal fungi. The expansion of the mycorrhizal mycelium and hyphae increases the plant roots network and nutrient availability.

Sufficient levels of organic matter encourages the growth of earthworms, which can increase water infiltration and soil aeration through tunneling. An increase in organic matter can encourage the growth of other microoganisms also that will suppress incidence of plant disease on many plant species. Research has shown that when the population of certain microorganisms increase they have the ability to suppress specific plant diseases such as pythium and fusarium as well as deleterious organisms like nematodes. Efforts to optimize the composting process in an attempt to increase the population of these beneficial microbes are being conducted (USCC Fact Sheet, 2008).

Biosolids effects on soil physical and chemical properties

One amendment which has been used for many decades to condition soil and replenish nutrients are class A biosolids. Class A biosolids is a designated term for heated and dewatered sewage sludge from waste water treatment plants that meets U.S. EPA guidelines for land application with no restrictions (US EPA, 2016). Because of this desigantion class A biosolids can be used legally as fertilizer on farms, gardens, sold to residents as compost or fertilizer. Class A biosolids have shown to have positive effects on both the physical and chemical effects when used as a soil amendment.

Biosolids tend to increase water infiltration rates and decrease bulk density. The studies reviewed showed a positive effect on certain plants when biosolids were used as a soil amendment. Peppers and tomatoes showed an increase in biomass but spinach, lettuce and radishes showed a decrease in biomass. Another concern with using biosolids as a soil amendment is that there is the potential for heavy metals and salt accumulation in certain plant species.

A two year study was conducted at three separate urban garden locations in Tacoma, Washington to study the effects of biosolid product applications on select parameters of the soil. Each of the three sites had six subplots a piece to test the effectiveness of two different types of biosolid products. Each biosolid product was used at a rate of 200 Mg ha^{-1} dry weight per year. For each biosolid product two subplots received 200 Mg ha^{-1} dry weight the first year and one of those two subplots received an additional 200 Mg ha^{-1} dry weight the second year (McIvor et al. 2012).

Biosolids have been used for many years as a twofold approach to dispose of waste in a more environmentally friendly manner and utilize a nutrient rich amendment to increase crop yields. With this approach however, concerns over metal and nutrient accumulation in plants have persisted. Not only could this be a concern for human health via the ingestion of these crops leading to unsafe levels of heavy metals being introduced to humans via ingestion. Using biosolids as an amendment could lead to lower crop yields and additional plant stress through excessive metal and nutrient availability and uptake. Biosolids were added at the rate of 0, 4.6 and 9.2 t ac^{-1}, on a dry weight basis (Maruthi Sridhar et al. 2014). Five types of plants (pepper, tomato, collard, lettuce, and radish plants) were utilized to assess the differences in varying plant species.

It was found that Na levels in all five plant types increased in the plant roots with increased doses of biosolids. Radish, collard and pepper plants grown in the 9.2 t ac^{-1} biosolid group showed the most significant increase in Na root uptake out of the five types of plants. Shoot uptake displayed significant differences for N, Mn, and Na in all five plant species with increased biosolid application rate. Plant biomass showed significant increase for the pepper plants in the 4.6 and 9.2 t ac^{-1} groups and tomato plants in the 9.2 t ac^{-1} group. Radish growth showed significant decrease in both the 4.6 and 9.2 t ac^{-1} groups.

Hypothesis

A low cost amendment and or microbial treatment could improve soil conditions in the Oakhill location to increase crop health and yield.

Additionally it is hypothesized that using and amendment in combination with a microbial treatment will produce better yields than just adding an amendment alone. The microbial treatment can act in a beneficial symbiotic manner with the host plant and provide additional nutrients which the amendment as a stand-alone treatment could not.

Objectives

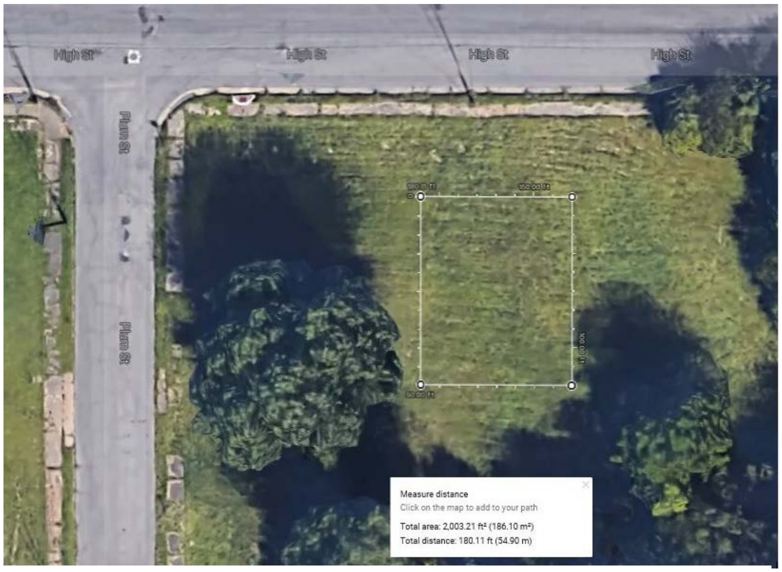
To assess if the amendments and or microbial treatments can improve soil quality and increase available nutrients to improve crop yields the following objectives will be analyzed.

1. Conduct a preliminary site assessment to determine if there are any areas of concern with possible contamination, determine where the best location at the site to establish the garden.
2. Analyze the soil at the site for its properties and undertake amendment and or microbial treatment combinations to improve yields of common garden crops of three varieties: leaf (lettuce), root (radish), and fruit (tomato).
3. Measure the physical, chemical and biological soil quality parameters along with the crop yields and nutrient content in the crops after harvest.
4. Statistically draw conclusions from the findings to determine which amendment and or treatment combinations would best improve the site's soil quality and increase crop yields.

Chapter 3 Materials and Methods

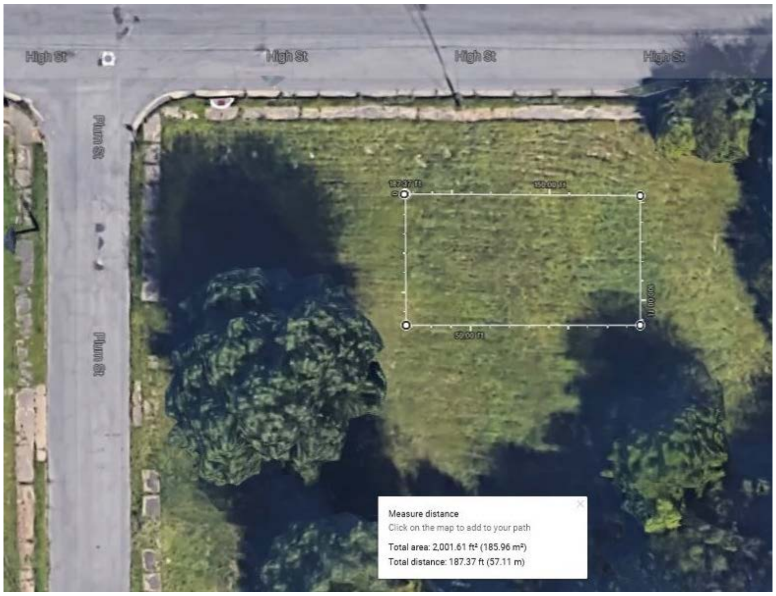
3.1 Site and Soil Description

The site under investigation is located on the west side of Youngstown in the Oakhill district, on a lot at the corner of Plum and High streets. Youngstown, located within Mahoning County, has a Region 6 soil classification (USDA, 2004), and as such the soil at the field site falls within this agricultural soil classification, despite decades of residential disturbance. Some of the characteristics of this soil is a low clay content and low amounts of organic matter in the top ten inches of soil. Glacial deposits in this region can range from



Measure distance
Click on the map to add to your path
Total area: 2,003.21 ft² (186.10 m²)
Total distance: 180.11 ft (54.90 m)

Figure 3 Location Selection 2 for the Community Garden



Measure distance
Click on the map to add to your path
Total area: 2,001.61 ft² (185.96 m²)
Total distance: 187.37 ft (57.11 m)

Figure 2 Location Selection 1 for the Community Garden coarse to finer textured soils. The coarser textured soils are mostly located in the southern portion of the region. Areas with fine texture soil are easy to till due to the low clay content found in this region (USDA, 2004).

Soil was collected from the Oakhill location using simple criteria which would be used by the community in the event of establishing a community garden. The simple criteria used were; a minimum buffer zone of fifteen feet was established between High Street to the north and Plum Street to the west. The site was visually surveyed and optimal subplots was selected based on a few considerations. Tree cover, root interference, and gradient were considered in selections of site location for an urban garden. These criteria were considered and the subplot was selected to eliminate influences which could affect crop growth.

Based on the criteria, two separate subplots were selected and are shown in Figures 2 and 3. These subplots had minimum tree interference, both in shade and root interference and were flat. The only area that had a slight slope was close to the sidewalk by High Street. All soil collection was done from the two areas selected. A measuring tape was used to establish the northwest and northeast corners of the subplots. The corners were marked and the pacing method was used to collect soil from the designated areas. A spade shovel was used to collect soil to a depth of twenty centimeters.

To obtain enough soil to conduct the study soil samples were collected on several different occasions. The total amount of soil collected was > 150 kg of dried soil. Due to the amount of soil needed for the study and the size of the collection area; it was determined that a grid collection system was not necessary and an accurate representative sample was obtained. A half inch field sieve was used during collection to remove rocks and debris (glass, plastic, etc..) from the samples collected. To obtain a homogeneous mixture the soil collections were combined and thoroughly mixed in a large plastic bin after being dried at 105^o C for 48 hours and sieved using a 2 mm sieve.

3.2 Soil Amendment/Microbial Treatment Description

Table 2 Descriptions of amendments and microbial treatments used in soil.

Amendment/Microbial Treatment	Soil to Amendment Ratio
None	-
Compost	25% by volume
Biosolids	2.5% by Dry Weight
AMF	Per Instructions
AMF/Bacteria Mix	Per Instructions
Compost + AMF	25% (Compost) by volume and (AMF) Per Instructions
Biosolids + AMF	2.5% (biosolids) by Dry Weight and (AMF) Per Instructions
Compost + AMF/Bacteria Mix	25% (Compost) by volume and (AMF/Bacteria) Per Instructions
Biosolids + AMF/Bacteria Mix	2.5% (biosolids) by Dry Weight and (AMF/Bacteria) Per Instructions

The *Mycorrhizal Fungus and Rhizobacteria* was purchased from MycoGrow™ and came in a soluble, 1 oz. packet. The packet contained six species of *Glomus* AMF which are viewed as ecologically important symbiotic plant endomycorrhizal fungi and the largest known genus of AMF (Schwarzott et al. 2012). The other endomycorrhizal fungi in the microbial treatment are of the species *Gigaspora* and *Paraglomus* which is a separate phylotype of AMF. These species are obligate symbionts with plants since they grow structures in the roots of the plants and extend the hyphae out of the root and into the soil (Torrecillas et al. 2012).

Some of the ectomycorrhizal fungi included in the microbial treatment were two species of *Laccaria* have been shown to increase phosphate uptake in plants (Desai et al. 2013). *Laccaria bicolor* showed an increase in phosphorous uptake in *Populus tremuloides* when lower concentrations of phosphorous were available. Other ectomycorrhizal fungi included in the mix, *Rhizopogon sp.,* have been studied as symbionts which can reduce stress from high salinity and metal concentrations (Ducic et al. 2008); while others have been shown to play a role in disease control *Trichoderma sp.* (Howell 2003).

Beneficial bacteria species included in the mix were of the one *Azotobacter,* six *Bacillus,* two *Paenibacillus and* two *Pseudomonas species*; along with the specially formulated amendments kelp, humic acid and vitamins to encourage proliferation of the microbial organisms. The MycoGrow™ Micronized Endo/Ecto Seed Mix--1 oz contained four Endomycorrhizal fungus from the *Glomus genera* and ectomycorrhizal fungi from the *Rhizopogon, Pisolithus,* and *Scleroderma species.*

3.3 Plant Growth and Harvesting Description

All seeds used were germinated prior to sowing them into soil. The seeds were placed between two pieces of paper towel moistened with deionized water and set on trays. A piece of plastic wrap was placed over the trays to prevent moisture loss. The trays were then placed in a growth chamber for four days at 21.5^{o}C. The germinated seeds with the largest or most numerous roots were selected for sowing and sown according to the instructions on the packages.

All plant types were planted on the same day; October, 5th, 2015. To start potted plants, 150 mL of water was added to each soil filled pot during seed planting. Roughly half of the 150 mL was initially added to the soil without any seeds to moisten the soil. After the seeds were planted at proper depth; a quarter inch for the lettuce and tomato crops and a half inch for radish they were covered by soil, the other half of the water was added.

For the plants grown with the fungus microbial treatment the instructions were followed for adding the spores during planting. Germinated seeds were placed in the soil at the proper depth and The MycoGrow™ Micronized Endo/Ecto Seed Mix powder was added with a small spatula to the roots of the germinated seeds then covered with dirt. The plants for the Bacteria Mix treatment were watered with the solution during planting and then three additional times. The Bacteria Mix solution was made up per instructions on the packet.

Since the crops were planted during late fall they were grown for a three month period in the Ward Beecher to ensure all treatments would have enough biomass for nutrient analysis of both the shoot and root mass. The crops were going to be grown for a two month period originally but certain treatments did not look as though they would have enough dry biomass to test per the selected procedure. A reduction in sunlight intensity and hours coupled with cooler temperatures seemed to effect the growth rate of the crops. Tomato plants were harvested on January 1st 2016 lettuce on January 7th 2016 and radishes on January 12th 2016.

Plants were removed from their pots and soil was gently broken from the root mass. The plants were then sectioned into root and shoot sections and thoroughly rinsed with water to remove ensnared soil particles. Roots from tomato and lettuce plants were rinsed in a fine mesh sieve so root matter would not be lost in the process. This process was repeated several times until the roots looked clean of soil particles. After rinsing of the plant sections they were patted dry with paper towels and weighed. Plants were dried in an oven at 105°C for 24-48 hours until all moisture was removed from the plant tissue.

3.4 Particle Size Analysis

The soil texture was assessed by utilizing the hydrometer method which determines the fractions of sands (< 2000-50 μm), silts (< 50-2 μm), and clays (< 2 μm) based upon sedimentation rates. The soil was prepared for the particle-size analysis by drying the soil at 105° C for at least 24 hours to remove residual moisture and then sieved using two millimeter sieve (Soiltest, Inc ASTM E-11). After the initial soil preparation the particle-size analysis method was conducted using 40 grams of soil in duplicate. Prior to conducting the hydrometer measurements soil was pretreatment with hydrogen peroxide to remove organic material as outline in the method (Gee and Bauder 1986). Organic matter can act as a flocculating agent in soils causing particles to form conglomerates which will not disassociate without an oxidizing agent. Without removing organic matter from the soil settling rates of the particles can be altered, producing erroneous results. The oxidizing agent selected for removal of organic matter was hydrogen peroxide (H_2O_2) (Gee and Bauder 1986). The samples had 25 mL of deionized water to them and a stirring rod was used to mix the soil and water together; aliquots of 5 mL of H_2O_2 were added and stirred.

The samples were put in the oven and heated at 105°C until the reactions ceased. This process was repeated until upon addition of the H_2O_2 reactions had completely ceased. The soils were then dried completely in the oven at 105^{o} C, removed and allowed to cool. After organic matter removal, the soil was soaked approximately seventeen hours in 100 mL sodium hexametaphosphate (NaHMP) dispersion solvent and 250 mL of deionized water. This solution has soluble phosphates which prevent flocculation of soil particles from occurring and keep particles in a suspended state (Gee and Bauder 1986).

The mixtures were transferred to a blender and mixed on high for five minutes then transferred to 1000 mL graduated cylinders. The blender was thoroughly rinsed with DI so all the contents were transferred into the graduated cylinder and the volume were brought to volume with DI water. The graduated cylinder was covered using parafilm to create a water tight seal and inverted for one minute to mix the contents (Gee and Bauder 1986). The cylinder was placed on the table and a hydrometer (Fisher ASTM 152H) was gently inserted and allowed to stabilize. Hydrometer readings were taken at 30 seconds, one minute and three minutes along with temperature readings (Woodco M 2157 thermometer).

After the first three readings were taken, the hydrometer was removed and parafilm was used to seal the graduated cylinder. The inversion process was repeated and readings were taken after 30 seconds, one, three, ten, thirty, sixty, 90, 120 and 1440 minutes. The hydrometer was removed and rinsed with DI water in between all of the readings accept for the thirty second and one minute reading. The temperature was also taken right before each reading and rinsed in between. The hydrometer readings along with temperature data was used to determine the soils texture.

The hydrometer readings were input into a Hydrometer Particle Size Calculator developed by Stillwater, OK Soil Survey Office. The program determines the soil texture in correlation with the United States Department of Agriculture (USDA) Natural Resources Conservation Service Texture Triangle (USDA, 1998). The Hydrometer Particle Size Calculator classifies soil type based upon settling times of the individual particles and viscosity of the suspension; the resulting percentages of sand, silt and clay are output in an Excel file and represented on the USDA, Texture Triangle.

3.5 pH and Conductivity Analysis

The role soil pH plays in plant nutrition is crucial and if the pH is too acidic or basic nutrients will become unavailable to the plants. The pH of the soils used in this study were measured using a pH/temperature combination probe (Accumet probe and Oakton meter). A standard method utilizing a 1:1 ratio of soil weight to deionized water volume (10 g soil:10 mL DI water) was used (G. Thomas 1996). The mixture was stirred for two minutes using a glass stir rod. Immediately after stirring the pH/temperature probe was lowered into the solution and a reading was taken once the probe stabilized.

The soil conductivity was measured using a ratio 1:3.5 and 1:3 soil weight to deionized water. Soil samples were weighed to as near as 10 grams as possible into beakers and the deionized water was added using a pipette. A glass stir rod was used to stir the samples for 10 minutes; after stirring the samples, a 10 minute resting period for sedimentation to occur was allotted. A conductivity probe (Hach Session 5) was lowered into the supernatant and a conductivity reading was recorded after stabilization.

3.6 Organic Matter Analysis

A direct estimation of organic matter was conducted on the soils using the Loss-on-ignition method (Nelson and Sommers 1996). This method was chosen because it can provide a quantitative estimate of the organic matter content. This method has some limitations when administered to soil with high clay content and low organic matter, although the soils used in this study did not fit this criteria. Organic matter heated at high temperatures will oxidize, resulting in the loss of the compounds via the ignition process transforming them into volatile organic compounds (VOCs) (Nelson *et al.* 1982). The analysis of the sample weights before and after can be used in Equation 1 to determine the amount of organic matter present.

$$LOI, \% = \frac{Weight_{105} - Weight_{400}}{Weight_{105}} \; x \; 100 \qquad \text{Eq. 1}$$

Various temperatures and ignition times have been studied to quantitatively determine the percentage of organic matter in soils. At high temperatures (> 750° C) carbonates can decompose and dehydroxylation of phyllosilicates can occur (Nelson et al. 1982). The various studies found that ignition of soils between temperatures of 400° C – 450° C will result in the total removal of organic matter and minimal dehydroxylation of clay minerals. Therefor the method heats the sample at 400° C for eight to sixteen hours (Ben-Dor & Banin, 1989). A U.S.A. Standard Testing Sieve ASTM E11 Specification 300 µm sieve was used to process the soil and obtain the < 0.4 mm particle size required by the method.

To remove residual moisture from the porcelain crucibles were heated at 400°C for 2 hours and then cooled in a desiccator. Crucibles were weighed after cooling and 3.00 grams of sample were weighed into crucibles (Fisher Scientific accuSeries analytical balance). Samples were heated at 400°C for 16 hours in Thermolyne series 1400 muffle furnaces. Samples were removed from the furnace and cooled in a desiccator; a final weight was taken after the samples and crucibles reached room temperature and organic matter percentage was determined using Equation 1.

3.7 Total Metal Analysis for Soil

Total metals and nutrients in soil were tested for using the US EPA method 3051. This method utilizes nitric acid (HNO_3) for a total digestion of soil samples. Samples were weighed out to as near to 0.500 grams as possible and transferred into polyvinyl microwave digestion tubes using a 1:1 nitric acid to deionized water mixture to ensure total transfer of the sample. Using a pipette, 10 mL of HNO_3 was added to each polyvinyl tube containing a sample. In addition, spiked samples were analyzed using the same method for quality control purposes. The tubes were loaded into the microwave digester (CEM Mars 6 One Touch), and the preprogrammed EPA 3051_30 method run. The soil digest were analyzed using an Inductively Coupled Plasma - Atomic Emissions Spectroscopy (ICP-AES, Thermo Scientific iCAP 6000 series).

3.8 Plant Available (Mehlich III) Analysis for Soil

Plant available nutrient concentrations is soils were determined using the Mehlich III extraction. Mehlich III is a mixture of ammonium nitrate, ammonium fluoride ethylenediaminetetraacetic acid, acetic acid and 1M nitric acid (Amacher 1996). A ratio of 1:10, soil to Mehlich III was used for all samples and shaken by hand for 10 minutes and then filtered through Whatman no. 40 filter paper. The filtrate was collected in 20 mL tubes and analyzed on ICP-AES (Thermo Scientific iCAP 6000 series) for metals and nutrients.

3.9 Total Nitrogen Analysis

Soil samples for the nine soil/amendment and or microbial treatment combinations were sent to Penn State's Agricultural Analytical Services Laboratory for analysis of total nitrogen. An analysis was conducted by the laboratory for total nitrogen using the combustion method also known as the Dumas method.

3.10 Inorganic Nitrogen Analysis

Nitrate & Nitrite

Nitrate and nitrite levels in soils were analyzed by extracting them using a dilute KCl solution. A 0.01 M solution of KCl was used to extract exchangeable nitrate (NO_3^-) and nitrite (NO_2^-) (Mulvaney, 1996). Samples were weighed into screw cap bottles and 0.01 M KCl was added at a ratio of 10 mL of extraction solution for every 1 gram of soil. The samples and extraction were shaken for an hour with a Burrell Wrist Action Model 75 shaker. After agitation the samples were filtered through Whatman no. 42 filter paper and the filtrate was collected for analysis via liquid ion chromatography system (Thermo Dionex ICS-1100 in conjunction with Chromeleon 7 software).

Ammonium

Exchangeable ammonium (NH_4^+) was extracted from the soils using a 2 M KCl extracting solution and the filtrate was analyzed via the colorimetry method (Mulvaney, 1996). Samples (4.0 grams) were weighed and mixed with 4 mL of extracting solution. The samples were agitated using a wrist action shaker for 1 hour. Samples were filtered through Whatman no. 42 filter paper and the filtrate was collected for analysis. Known standards of 0, 2, 4, 6, 10, and 20 µg of NH_4^+-N were made in accordance with the method to establish the calibration curve. Color was developed using sodium salicylate-sodium nitroprusside, buffered hypochlorite and ethylenediaminetetraacetic acid reagents (Mulvaney, 1996). Absorbance readings were taken at 667 nm using a Thermo Scientific Genesys 10S Vis Spectrophotometer.

3.11 Plant Tissue Analysis

Plant tissue was digested using a wet digestion technique that utilized HNO_3 and 30% H_2O_2. Samples were weighed out to 0.500 grams in digestion tubes and mixed with 5 mL of HNO_3. A reflux cover was put over the samples as they soaked in the HNO_3 overnight. The samples were heated to 120°C for an hour in a block digestion unit. The samples were removed and allowed to cool and 8 mL of H_2O_2 was added to destroy organic matter (Jones & Case, 1990). Additional HNO_3 was added to samples to keep them from drying completely and the digestion process was repeated; additional H_2O_2 was added between 1 hour digestion periods and digestion was carried out until the solutions were clear. The samples were then dried at 80°C without the reflux covers until almost complete dryness. Samples were diluted to a final volume of 10 mL with a 1:10 HNO_3 acid. The sample digests were analyzed with the Thermo Scientific iCAP 6000 series ICP-AES.

3.12 Soil Microbe Analysis

Microbial plating for all soil, amendment and or biological treatment combinations was conducted. This was done to determine if any combination increased the microbial population in the soil. The plating’s were conducted using Tryptic Soy agar (TSA) and Sabouraud Dextrose agar (SDA) plates. TSA is a common media used for general bacterial growth and SDA is a common media used for fungal growth. Quantitative analyze for both bacteria and fungus was based on percent plate coverage. Preliminary plating's we conducted to determine an appropriate dilution ratio of soil to deionized water. After establishing a suitable ratio for enumeration of bacterial and fungal growths, microbial plating was conducted. It was determined that a ratio of 1:100,000 would be appropriate for enumeration purposes. Soil samples were weighed into screw cap containers and sterilized deionized water was added at a ratio of 1:100 soil to DI water was added.

The samples were shaken on a Burrell Wrist Action Model 75 shaker for 30 minutes. Through serial dilutions the final ratio of 1:100,000 was achieved. In duplicate 100 μL of final dilution aliquots were plated on TSA and SDA media and plate spreaders were used to evenly distribute the samples. TSA plates were incubated in a Thermo incubator at 35°C for three days and SDA plates were incubated at 25°C for five days which are common temperature and time periods used for the respective microbial growths. Enumeration of colony forming units (CFUs) and percent plate coverage was conducted for all media plates.

3.13 Statistical Analysis

Several statistical analysis of data were conducted to draw conclusions from the data obtained from the various soil and plant tissues tests. The main focus will be to analyze data aimed at determining what accounts for differences if any exist in the dry biomass of plant sections. To determine if correlations exist between the various soil parameters and nutrient concentrations in plant tissue and biomass exist Pearson Correlations will be conducted. Significant correlations at the 0.05 and 0.01 levels will be marked and discussed. Further from the correlations found Backwards stepwise regressions will be conducted and analyzed to determine what factors had the most significant impact on each of the plant section's biomass.

To determine how the different amendment and microbial treatments effected plant growth (biomass), available and total soil nutrient concentrations and nutrient uptake in plants ANOVA was used to compare treatments. For each type of plant, ANOVAs were conducted by placing the amendment and or treatment (Group) in as the Factor variable and then the continuous data (Biomass, Mehlich III, Soil Totals and Plant Tissue Totals) in the as the dependent variables. A Homogeneity of Variance test was conducted with the ANOVA test to determine which Post Hoc test to run.

Chapter 4 Results and Discussions

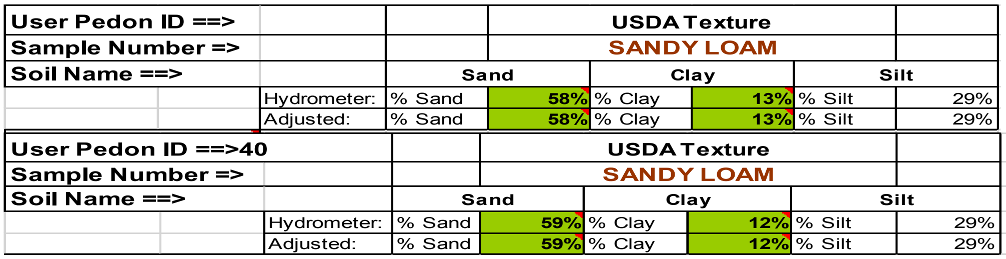
The soil amendment and/or microbial treatments were analyzed for the following parameters: pH, organic matter, electrical conductivity, microbial quantities, and nutrients including, total and plant available. The plants were analyzed for biomass and total nutrients. Statistically significant relationships between soil characteristics and plant growth were determined using Pearson correlations, backwards stepwise regressions, and ANOVA. IBM SPSS (PASW Statistics 18) was used to conduct the statistical analysis of these parameters.

4.1 Particle Size Analysis Results

The initial soil from the Oakhill site was analyzed for particle size analysis after mixing to establish the type of soil present at the site. The soil was determined to be a sandy loam. The texture profile was found to be composed of 58-59% Sand, 29% Silt, and 12-13% Clay. For the Hydrometer Particle Size Calculator from Soil Survey Office Stillwater, OK, the following data was required by the program; hydrometer readings and temperature readings at 0.5,1, 5, 10, 30, 60, 90, 120, 480 and 1440 minutes, the dry weight for the samples, blank readings, and HMP solution concentration (Soil Survey Office, NSSC et al. 1998). The program provided several outputs for the determined particle size distribution and texture of the soil.

A table of the results was provided and gave the percentages of the sand, silt and clay along with the classification of the soil (Table 3). In addition a USDA soil texture triangle display was provided (Figure 4) and a summation curve (Appendix).

Table 3 Output from the Hydrometer Particle Size Calculator with % sand, silt and clay for the Oakhill soil.



User Pedon ID ==>				**USDA Texture**				
Sample Number =>				**SANDY LOAM**				
Soil Name ==>			**Sand**		**Clay**		**Silt**	
		Hydrometer:	% Sand	**58%**	% Clay	**13%**	% Silt	29%
		Adjusted:	% Sand	**58%**	% Clay	**13%**	% Silt	29%

User Pedon ID ==>40				**USDA Texture**				
Sample Number =>				**SANDY LOAM**				
Soil Name ==>			**Sand**		**Clay**		**Silt**	
		Hydrometer:	% Sand	**59%**	% Clay	**12%**	% Silt	29%
		Adjusted:	% Sand	**59%**	% Clay	**12%**	% Silt	29%

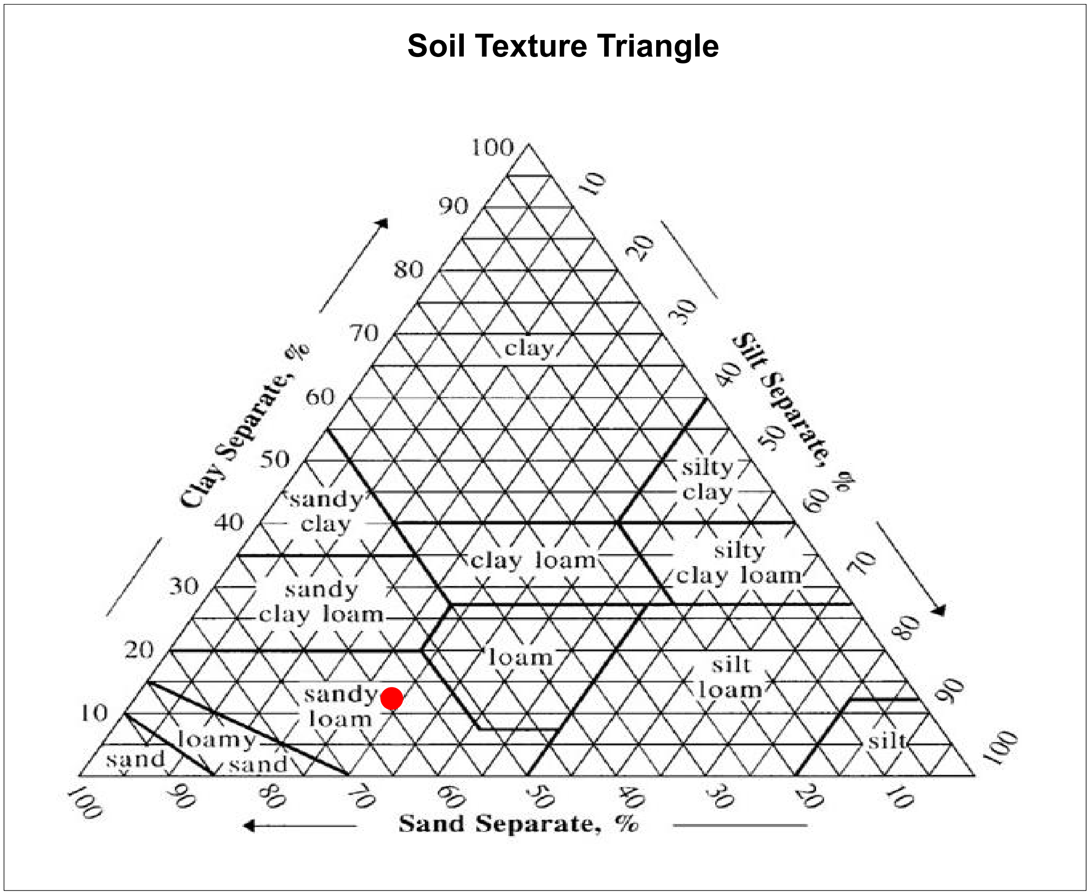


Figure 4 Soil texture triangle with soil texture identified for the Oakhill soil.

4.2 pH and Electrical Conductivity

The pH between the amendment/treatment combinations ranged from 6.06 -7.36. The pH for all samples was determined using a 1:1 ratio of soil to deionized water.

Table 4 Oakhill soil treatment and corresponding average pH and electrical conductivity.

	Control	Bacteria Mix	Fungus	Biosolid	Biosolid +Bacteria Mix	Biosolid+ Fungus	Compost	Compost + Bacteria Mix	Compost + Fungus
pH	6.06	7.28	7.35	7.36	7.11	7.08	6.92	6.25	6.33
EC (µs/cm)	545	667	578	1158	1056	1437	999	943	1087

The data (Table 4) indicates that the control had the lowest soil pH and electrical conductivity out of all the treatments. The soil with biosolid addition had the highest pH and the Biosolid + Fungus treatment had the highest electrical conductivity. All treatments were in the pH range of 6.0 – 7.5 which is an acceptable range for most crops. The Control soil was close to the low end of the range at 6.06 while the Biosolid and Fungus treatments were towards the higher end of the range at 7.36 and 7.35 respectively. The pH range of 6.2 – 7.3 as shown in Figure 1, is not a required standard range but provides a visual to show how different nutrient's availability is impacted as the pH changes. Most vegetable crops grow best at a pH between 5.5-6.5 with beets and cabbage having a preference between 5.5-7.5 (Nathan and Stecker 1999). None of the pH readings went beyond the suitable range and therefore would not be considered a problem for nutrient acquisition and plant growth.

The electrical conductivity (EC) ranged from non-saline (< 1000 µS/cm) to slightly elevated saline (≥ 1000 µS/cm) for the varying treatments. Biosolid and Compost amendments raised the soil EC above the Control. The addition of microbial treatments had a varying effects on the Control and amendments. The fungus treatment raised the EC in all three instances while the microbial treatment with bacteria lowered the EC on two occasions but when added to the control soil alone raised the EC. All EC amendments and/ or treatments were higher than the Control.

4.3 Organic Matter Results

Table 5 Average organic matter percentages for each amendment and /or treatment.

	Control	Bacteria Mix	Fungus	Biosolid	Bisolid+ Bacteria Mix	Biosolid +Fungus	Compost	Compost+ Bacteria Mix	Compost+ Fungus
%OM	7.36	7.39	7.26	8.11	7.31	7.9	8.14	7.7	7.94

The organic matter (OM) content for the various treatments showed no statistical difference among any of the amendment or biological treatments. The ranges between all treatments was from 7.26 – 8.14% OM. The Biosolid and Compost amendments increased the organic matter percent of the Oakhill soil from 7.36 to 8.11 and 8.14 respectively. The microbial treatments had no impacts on organic matter percentages. Both treatments reduced the OM in the Biosolid and Compost amendments as compared to the biosolids or compost alone. The Bacteria Mix treatment had a greater effect of reducing OM% compared to the Fungus treatment. Fungus reduced the OM in both Biosolid and Compost amendments by about 0.2%, whereas the bacteria reduced the OM in Biosolids by 0.8% and 0.4% in the compost. All amendments and treatments had less than a 1% change to OM compared to the Control.

Most agricultural soil contain 3-6% organic matter therefore, the organic matter content was determined to be well suited for plant growth especially with the soil texture of sandy loam with a relatively low clay content of 12-13% and a silt content of 29%.

The small solid particulates (clay and silt) would serve well for the purposes of cation exchange (nutrient adsorption) and provide readily available nutrients for plant uptake.

4.4 Soil Nitrogen Compounds Analysis Results

Table 6 Total nitrogen, ammonium (NH_4), nitrate (NO_3) for each amendment and/or treatment

	Control	Bacteria Mix	Fungus	Biosolid	Biosolid+ Bacteria Mix	Biosolid+ Fungus	Compost	Compost + Bacteria Mix	Compost + Fungus
Total N mg/kg	2000	2100	2000	2200	2100	2400	2300	2400	2300
NH_4^+ mg/kg	15.2	12.9	16.5	11.5	23.6	27.8	12.9	21.3	21.9
NO_3^- mg/kg	28.7	54.2	110.6	649.8	743.9	1504.7	66	211.7	65.1

The total nitrogen was between 2000 – 2400 mg/kg for all treatments. The Control and Fungus treatment had the lowest concentration of total nitrogen out of all the combinations with a concentration of 2000 mg/kg. The Biosolid+Fungus and the Compost+Bacteria Mix were found to have the highest levels of total nitrogen at 2400 mg/kg. The ammonium levels and nitrate levels however varied greatly amongst treatments. The ammonium levels found ranged from 12.9 mg/kg to 27.8 mg/kg. The ammonium levels were all higher than the 2 – 10 mg/kg range that is typically found to be sufficient for plant growth.

The testing for ammonium was conducted after harvest. Ammonium and nitrate levels can fluctuate greatly and depend on parameters such as temperature and moisture level. Since nitrogen testing was conducted after harvest this data can be used to compare the levels found between the amendment and or microbial treatments at that point. Concentrations of the various forms of nitrogen may have fluctuated during the duration of the study. However, all levels were found to be above the typical range. The Biosolid amended soil was found to have the lowest level of ammonium with 11.5 mg/kg while the Biosolid+Fungus combination had the highest level at 27.8 mg/kg.

The levels of nitrate ranged from 28.7 to 1504.7 mg/kg. This form of inorganic nitrogen had the largest range of the forms tested. The Control soil in this group was found to have the lowest concentration with 28.7 mg/kg and the Biosolid+Fungus was found to have the highest concentration of nitrate as well with a concentration of 1504.7 mg/kg.

4.5 Soil Melich III (Plant Available) Analysis Results

The plant available levels found in the soils which the tomato plants were grown in are listed in Table 5.5 below. The calcium and phosphorous levels for all of the amendment and or treatment combinations including the Control soil were in the very high range. The available potassium levels ranged from low to high between the various combinations while the magnesium levels ranged from high to very high. As specified in Table 7 Mehlich III concentrations for calcium are considered to be very high at levels above 1,790 lbs/acre or 895 mg/kg. Calcium concentrations in the Control, Bacteria Mix and Fungus treatments all had calcium levels in the 1300 mg/kg and the addition of the microbial treatments alone did not affect the available concentration much.

The addition of compost and biosolid increased the average calcium concentrations over the Control level by 700 to 800 mg/kg. Also both microbial treatments slightly increased the available Ca concentrations when used in combination with compost and biosolids. The potassium levels were the lowest in the Control soil compared to other amendment and treatments. The addition of the microbial treatments alone raised the mg/kg by 11-16 mg/kg when added to the Control soil. Both the biosolid and compost additions raised the available K. The microbial treatments both showed large increases when used in combination with biosolids and slight increases when used with compost.

The available Mg levels showed slight increases with the addition of Biosolid + a microbial treatment but showed substantial increases in the Compost and Compost + microbial treatments. The levels of available phosphorous tended to decrease from the Control concentrations with the addition of amendments and microbial treatments with the exception of the Bacteria Mix treatment which showed a slight increase of 17 mg/kg.

Table 7 Mehlich III nutrient concentrations in tomato soils

Mehlich III Concentrations in mg/kg (Tomato Soil)										
Nutrient	Ca	Cu	Fe	K	Mg	Mn	Ni	P	S	Zn
Control	1331	9.8	192	32	139	91	0.54	299	54	40
Bacteria Mix	1353	8.9	179	48	138	86	0.53	316	60	44
Fungus	1359	8.5	179	43	138	105	0.55	298	72	39
Biosolid	2143	8.6	123	55	141	58	0.46	284	60	32
Biosolid+Bacteria Mix	2326	8.1	114	104	158	59	0.46	268	91	32
Biosolid+Fungus	2400	8.2	119	114	165	55	0.45	278	74	33
Compost	2086	7.4	142	86	244	92	0.50	273	101	38
Compost+Bacteria Mix	2310	7.1	133	99	277	94	0.53	255	96	39
Compost+Fungus	2294	7.9	143	95	278	96	0.50	274	87	40

The plant available levels found in the soils which the radish crop were grown in are listed in Table 8 below. Like the tomato results Ca and P concentrations were all in the very high range, K concentrations however ranged from medium to very high between combinations while Mg available concentrations were very high. Calcium concentrations in the Control, Bacteria Mix and Fungus treatments all had calcium levels in the 1600 mg/kgs with no real difference with the addition of microbial treatments.

The addition of compost and biosolid increased the average calcium concentrations over the Control level by ~ 400 to 1200 mg/kg. Microbial treatments in combination with Compost increased the available Ca concentrations by about 300 mg/kg. The treatments used in combination with the Biosolids amendment showed a slight decrease (Bacteria Mix – 142 mg/kg) and a slight increase (Fungus + 307 mg/kg). The potassium levels were the lowest in the Control soil compared to other amendment and treatments. The addition of the microbial treatments overall had no effect while the additions of Biosolid and Compost increased the available concentrations with the Compost having the greatest effect.

The available Mg levels showed slight increases with all Biosolid combinations and a greater increase with the Compost combinations. The levels of available P concentrations were all found to be very similar.

Table 8 Mehlich III nutrient concentrations in radish soils

Mehlich III Concentrations in mg/kg (Radish Soil)										
Nutrient	Ca	Cu	Fe	K	Mg	Mn	Ni	P	S	Zn
Control	1599	9.6	172	50	160	64	0.51	286	51	46
Bacteria Mix	1673	11.2	179	52	166	63	0.56	289	55	51
Fungus	1628	8.7	184	50	168	76	0.55	272	65	45
Biosolid	2859	9.3	152	88	189	60	0.49	278	75	39
Biosolid+Bacteria Mix	2717	8.8	146	68	192	53	0.49	250	64	38
Biosolid+Fungus	3166	10.5	136	84	197	54	0.49	268	84	47
Compost	2074	7.3	144	126	255	81	0.40	258	92	39
Compost+Bacteria Mix	2364	6.9	145	146	309	101	0.43	232	100	43
Compost+Fungus	2395	7.7	156	136	289	101	0.46	252	83	43

The plant available levels found in the soils which the lettuce crop were grown had similar results to the tomato and radish crops and are displayed in Table 9. The Ca and P concentrations were all in the very high range, K concentrations were found to be medium to and Mg were all very high. The one noticeable difference was that the Ca concentrations which were much higher in all the Biosolid combinations in comparison to the tomato and radish soils. The Biosolid amendment had an available concentration of 4418 mg/kg compared to 2143 and 2859 in the tomato and radish Biosolid amendments respectively. Both microbial treatments used in combination with the Biosolid amendment showed a reduction in levels of ~ 800-900 mg/kg decrease with the Biosolid+Bacteria Mix showing a greater decrease to the Biosolid level.

Table 9 Mehlich III nutrient concentrations in lettuce soils

Mehlich III Concentrations in mg/kg (Lettuce Soil)										
Nutrient	Ca	Cu	Fe	K	Mg	Mn	Ni	P	S	Zn
Control	1722	9.9	164	37	151	52	0.55	232	65	47
Bacteria Mix	1708	9.3	159	42	149	59	0.55	225	75	46
Fungus	1738	9.0	166	44	152	59	0.54	234	63	46
Biosolid	4418	9.1	138	86	233	52	0.55	238	122	41
Biosolid+Bacteria Mix	3508	9.5	156	113	205	54	0.54	241	89	43
Biosolid+Fungus	3610	8.8	143	144	210	50	0.53	231	85	41
Compost	2616	7.9	170	146	310	73	0.47	226	94	50
Compost+Bacteria Mix	2960	7.8	147	186	344	72	0.54	210	100	53
Compost+Fungus	2805	8.0	139	182	328	74	0.52	209	97	51

4.6 Soil Microbial Analysis

The microbial plating to determine relative quantity of bacteria and fungus present in the different treatments showed increases under several of the different amendment and or treatments over the control. This is not a definitive measure of microbial quantity in the amendment and or treatments as only microbes which will grow on these media at these temperatures (Sutton 2011). This was done to see if certain treatments possibly increased microbial populations in the soil. For the microbial plating utilizing Tryptic Soy Agar (TSA) the Biosolid amendment had the highest percentage of plate coverage for all three plants. The Biosolid+Bacteria Mix and Biosolid+Fungus also had a higher percentage of coverage over other treatments including the Control. The Fungus treatment had the lowest plate coverage for all three plants.

The microbial plating conducted using Sabouraud Dextrose Agar (SDA) showed that the Compost amended soil had the highest percentage of plate coverage for all three type of plants. There was variation in treatments among the different types of plants showing there may be a relationship there where plant excrete different types of root exudates which can dictate or influence the microbial community populations in quantity and or it diversity to a significant degree.

Table 10 Average Percentage of Plate Coverage from Microbial Platings

	Control	Bacteria Mix	Fungus	Biosolid	Biosolid + Bacteria Mix	Biosolid + Fungus	Compost	Compost + Bacteria Mix	Compost + Fungus
Lettuce (TSA)	50	57.5	50	**87.5**	82.5	72.5	62.5	80	65
Radish (TSA)	42.5	47.5	20	**92.5**	82.5	82.5	47.5	55	62.5
Tomato (TSA)	30	65	22.5	**97.5**	87.5	85	55	62.5	65
Lettuce (SDA)	67.5	65	42.5	55	70	42.5	**100**	52.5	67.5
Radish (SDA)	60	25	70	35	75	87.5	**100**	97.5	92.5
Tomato (SDA)	25	35	80	47.5	82.5	92.5	**97.5**	92.5	60

4.7 Soil Total Nutrient Analysis Results

Total nutrients found in the soil amendment and or microbial treatments are listed in Tables 10-12 below and are included for reference purposes to show how concentrations differed among treatments.

Table 11 Total nutrient concentrations in tomato soils

Total Concentrations in mg/kg (Tomato Soil)										
Nutrient	Ca	Cu	Fe	K	Mg	Mn	Ni	P	S	Zn
Control	3776	41.2	21881	850	1795	534	14.2	1014	484	225
Bacteria Mix	3868	37.4	16953	689	1725	536	11.8	1149	473	210
Fungus	3514	37.5	16717	687	1555	548	12.2	1240	485	222
Biosolid	4820	40.5	16836	720	1471	512	11.4	1120	492	204
Biosolid+Bacteria Mix	7256	40.5	18198	910	1707	544	11.8	1129	607	198
Biosolid+Fungus	5807	39.7	17839	856	1602	512	11.6	1175	540	200
Compost	9454	31.6	18170	802	2239	841	10.8	1094	661	205
Compost+Bacteria Mix	7271	36.0	20736	929	2149	608	12.6	1181	612	215
Compost+Fungus	6395	35.8	18727	901	2082	564	12.2	1103	610	217

Table 12 Total nutrient concentrations in radish soils

Total Concentrations in mg/kg (Radish Soil)										
Nutrient	Ca	Cu	Fe	K	Mg	Mn	Ni	P	S	Zn
Control	3410	62.5	18615	748	1672	526	11.9	1018	434	236
Bacteria Mix	5091	41.2	22645	772	1907	660	13.4	1150	520	282
Fungus	6350	42.3	18300	832	2117	555	13.0	1182	490	289
Biosolid	7188	44.7	20127	804	1694	524	13.1	1067	485	231
Biosolid+Bacteria Mix	5609	41.8	19959	797	1679	577	12.6	1151	574	252
Biosolid+Fungus	6727	44.8	20171	878	1797	581	13.1	1130	542	263
Compost	6469	34.6	31730	1222	2405	617	15.6	1043	541	259
Compost+Bacteria Mix	7777	35.5	26021	1061	2454	611	13.9	1050	671	254
Compost+Fungus	8983	33.0	24910	1138	2779	668	13.7	1038	665	260

Table 13 Total nutrient concentrations in lettuce soils

Total Concentrations in mg/kg (Lettuce Soil)										
Nutrient	Ca	Cu	Fe	K	Mg	Mn	Ni	P	S	Zn
Control	4962	44.2	24546	878	1964	666	14.5	1139	675	243
Bacteria Mix	4205	41.1	21004	804	1912	627	13.9	1077	620	225
Fungus	3967	42.0	25519	825	1676	643	13.9	1161	722	240
Biosolid	7045	81.9	20229	897	1716	565	13.9	1104	727	273
Biosolid+Bacteria Mix	7318	41.8	22037	964	2063	548	13.8	1063	671	259
Biosolid+Fungus	6457	44.2	22208	1071	1841	625	14.4	1117	584	265
Compost	7885	37.7	19454	953	2165	658	12.1	1052	612	264
Compost+Bacteria Mix	13613	34.9	18183	1023	3069	747	11.5	1085	879	238
Compost+Fungus	12641	36.1	19374	1031	2998	823	11.6	1030	832	229

4.8 Plant Biomass Results

The comparison of the amendment and microbial treatment combinations for Tomato Shoots biomass can be seen in Figure 5.8. The figure shows that all treatments with the exception of Biosolid and Compost had lower average biomass weights than the Control soil. The Biosolid+Fungus treatment had the lowest average biomass weight of all treatments, followed by Fungus then Biosolid+Bacteria Mix. The Bacteria Mix, Compost+Bacteria Mix and Compost+Fungus also had lower average biomass weights then the Control did.

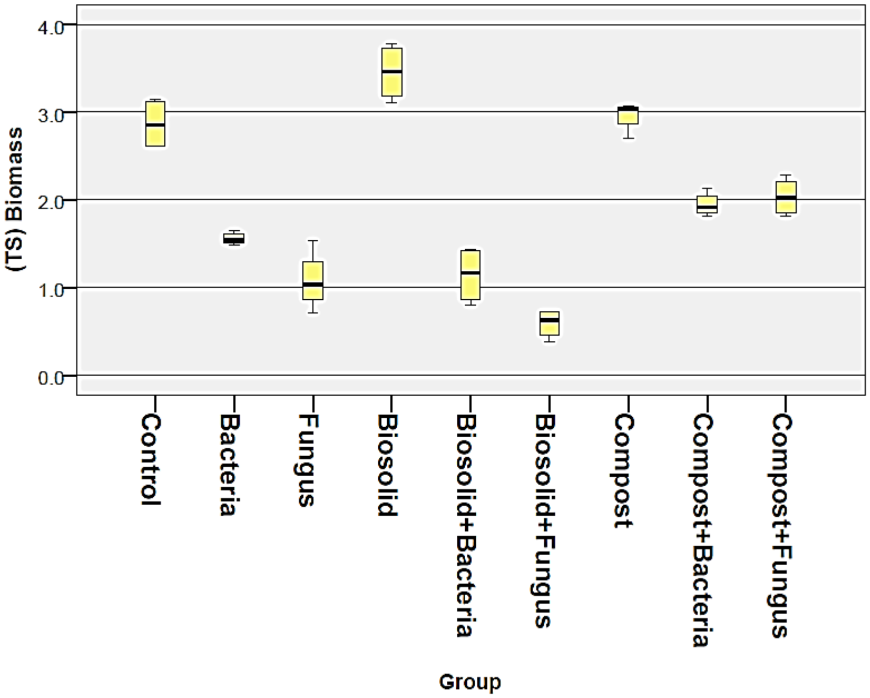


Figure 5 Box Plot of Tomato Shoot Biomass by Treatment showing Average, Upper and Lower Quartiles and Whiskers

Figure 6 Radish R1 and R2 grown in the Control Soil showing Root Rot.

The radish root biomass represented in Figure 7 shows that the Biosolid+Bacteria Mix amendment/treatment had the highest average weight out of all treatments but a large lower whisker extending ~ .3 grams below the lower quartile. The Control showed the second highest mean average followed Compost and Biosolid+Fungus. The radishes grown in soil with the Fungus microbial treatment had the lowest mean average of all treatments. Figure 6 is provided because two of the four radishes grown in the Control soil displayed rotting of the radish R1 and R2. This did not seem to effect the weight of R1, the radish seemed normal until it was cut open. The weight of R2 could have been effected as the outside had a shriveled look and grew irregularly.

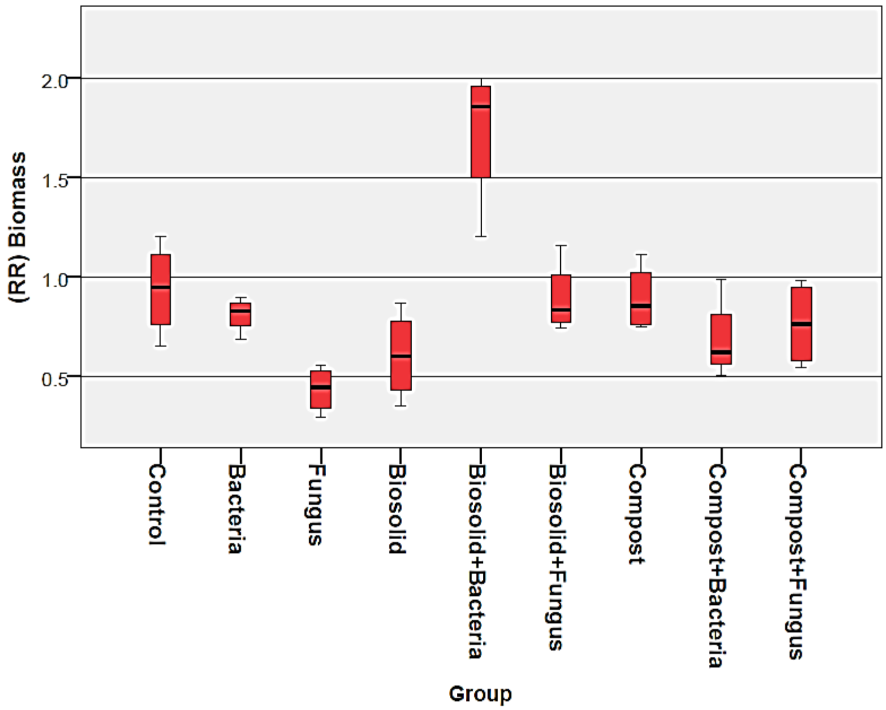


Figure 7 Box Plot of Radish Root Biomass by Treatment showing Average, Upper and Lower Quartiles and Whiskers

Analysis of the lettuce shoot biomasses from the box plot shows that lettuce grown in the Control soil had the highest mean average followed by lettuce grown in soil with the Bacteria Mix microbial treatment added followed by the Fungus treatment. The Biosolid+Fungus treatment had the lowest average shoot weight of all the treatments.

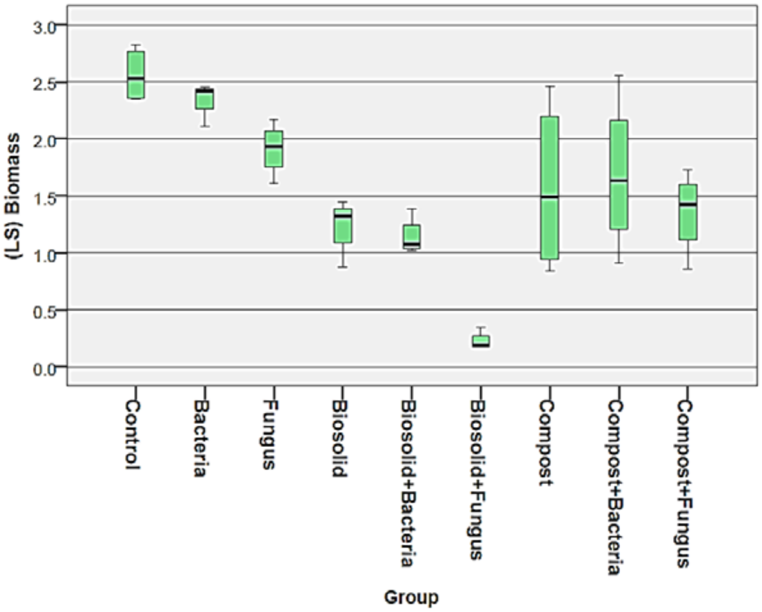


Figure 8 Box Plot of Lettuce Shoot Biomass by Treatment showing Average, Upper and Lower Quartiles and Whiskers

4.9 Plant Tissue Analysis

The analysis of the nutrient concentrations in plant tissues showed that the different amendments and microbial treatments had an effect on nutrient uptake and incorporation in plants. Also different crop types; root, leaf and fruit responded different to nutrient loading into plant tissue and had varying results and trends specific to crop type.

For tomato stems the microbial treatments demonstrated an effect of increasing certain nutrient concentrations in tomato stem tissue for several of the elements when added to the Control soil. Calcium, iron, potassium and sulfur showed increased levels with the addition of both the Bacteria Mix and Fungus treatments. All treatments with biosolid resulted in a mean increase in Ca, K concentrations but a decrease in Mg, Mn, P and Zn compared to the Control. Treatments involving Compost increased K in stem tissue and decreased Cu, Mg, Mn, P, S and Zn from levels compared to the Control.

The Bacteria Mix treatment resulted in the highest mean concentrations of Cu, Mg, P, S and Zn in stem tissue. Calcium and Fe concentrations were highest in the stem tissue of Biosolid+Fungus and Mn concentration was highest in stem tissues grown in Control soil.

Table 14 Nutrient Concentrations found in Tomato Stems

Tomato Stem Nutrient Values (mg/kg)

	Ca	Cu	Fe	K	Mg	Mn	P	S	Zn
Control	13712	9.9	75	27134	5136	**120**	4365	2839	254
Bacteria Mix	20465	**12.4**	109	34327	**5751**	83	**6238**	**5042**	**364**
Fungus	19247	10.0	124	40028	2680	74	2813	4199	223
Biosolid	22761	11.1	94	40101	4409	55	2608	4166	116
Biosolid+Bacteria Mix	24752	10.2	72	**51413**	3177	46	2128	3927	125
Biosolid+Fungus	**30953**	7.7	**177**	51364	3930	48	1372	1700	181
Compost	12874	5.2	61	38489	1995	39	3047	1913	128
Compost+Bacteria Mix	13766	5.5	78	40360	1799	38	3017	1990	129
Compost+Fungus	13618	5.1	59	42653	1872	29	3171	2069	135

Nutrient uptake into radish root tissue showed some trends among the amendment and microbial treatment combinations. The radishes grown in the Control soil had the highest average concentration for potassium, magnesium, manganese, phosphorous, sulfur and zinc. Radishes grown in the Biosolid amendment had the highest levels of calcium, copper and iron.

Table 15 Nutrient Concentrations found in Radish Roots

Radish Root Nutrient Values (mg/kg)

	Ca	Cu	Fe	K	Mg	Mn	P	S	Zn
Control	10672	8.7	209	**46510**	**4726**	**37.8**	**13707**	**16460**	**173**
Bacteria Mix	4988	4.9	109	32062	1378	16.2	3890	4123	102
Fungus	4600	9.8	425	41013	2024	40.1	6943	6468	140
Biosolid	**12714**	**12.4**	**714**	45248	2030	34.1	3207	6028	50
Biosolid+Bacteria Mix	8157	6.0	280	37960	2944	18.4	8536	7253	69
Biosolid+Fungus	8718	5.1	139	41166	1632	17.1	2887	4078	60
Compost	7272	4.9	78	46621	2158	15.8	6722	6046	46
Compost+Bacteria Mix	8268	2.5	105	45972	1879	14.1	2313	2372	60
Compost+Fungus	9556	4.0	138	43832	4030	12.9	8164	7632	74

Compared to the Control certain amendments/microbial treatments showed a tendency to increase or decrease certain nutrients into the lettuce shoot tissue. When the Bacteria Mix and Fungus treatments were added as stand-alone they decreased the concentration of all nutrients in the lettuce shoot tissue. However when the microbial treatments were added in combination with the Compost or Biosolid amendments they did not have the same effect. The Biosolid+Bacteria Mix and Biosolid+Fungus increased the Ca, K and S concentrations compared to both the Control and Biosolid treatments. Additionally the Biosolid+Fungus increased Fe and Mg over the Control and Biosolid.

The three treatments involving Compost showed a decrease in nutrient uptake of Ca, K, Mg, Mn, P, S and Zn compared to the concentrations in the Control lettuce. The Biosolid+Fungus treatment had the highest level of Ca, K, Mg and S of all the treatments and also had the lowest average biomass of all the groups.

Table 16 Nutrient Concentrations found in Lettuce Shoots

Lettuce Shoot Nutrient Values

	Ca	***Cu***	***Fe***	***K***	***Mg***	***Mn***	***Ni***	***P***	***S***	***Zn***
Control	11540	**12.18**	256	44848	6386	**401**	0.52	**8505**	2737	258
Bacteria Mix	8798	6.85	148	34307	2277	225	0.41	4900	1878	233
Fungus	11040	8.31	277	36740	2994	310	0.38	3677	1682	**283**
Biosolid	14268	11.74	171	62246	3335	77	0.37	4585	2505	64
Biosolid+Bacteria Mix	18432	11.23	298	58516	5926	130	0.48	7652	3537	164
Biosolid+Fungus	**25273**	10.96	**521**	**63716**	**19784**	157	**0.89**	8201	**4041**	198
Compost	9504	4.96	103	40777	2138	89	0.18	4474	1324	70
Compost+Bacteria Mix	10649	5.46	121	42916	2443	99	0.33	3926	1172	50
Compost+Fungus	7459	3.65	67	33700	1550	51	0.15	3603	916	38

4.10 Pearson Correlation

Pearson Correlations were conducted to try and find significant correlations between the biomass of plant sections and soil characteristics (pH, OM, Available and Total Nutrients) and nutrient concentrations in the plant tissues. The correlations found were also used to establish applicable criteria for conducting backwards stepwise regression for determination of the most likely parameter which effected the biomass of specific plant sections.

Lettuce

Out of the three plants; lettuce was found to have the most correlations between biomass of plant sections (root and shoot) and soil data and nutrient levels in plant tissue. In Table 18 significant correlations at the (0.05)* and (0.01)** levels between lettuce root biomass and soil properties are displayed. Significant correlations between Nitrate and available Zn showed significant correlations at the 0.01 level and available Ca and total

Zn showed correlations at the 0.05 significance level. The nitrate, available Ca and total Zn showed a negative correlation to lettuce root biomass while available Zn showed a positive correlation.

Table 17 Pearsons Correlations between Lettuce Root Biomass and Soil Properties

		N03	**(M3) Ca Avg**	**(M3) Zn Avg**	**(T) Zn Avg**
(LR) Biomass Avg	Pearson Correlation	-0.846**	-0.685*	.819**	-.726*
	Sig. (2-tailed)	0.004	0.042	0.007	0.027
	N	9	9	9	9

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

There were five significant correlations found between nutrient concentrations in lettuce root tissue and lettuce root biomass. Calcium and nickel concentrations in the lettuce root tissue were found to be statistically significant at 0.01 and copper, iron and magnesium concentrations were significant at the 0.05 level. All five of the correlations between nutrient concentrations in the root tissue and biomass were negative.

Table 18 Pearsons Correlations between Lettuce Root Biomass and Nutrient Concentration in Lettuce Root Tissue

		(LR) Ca Avg	**(LR) Cu Avg**	**(LR) Fe Avg**	**(LR) Mg Avg**	**(LR) Ni Avg**
(LR) Biomass Avg	Pearson Correlation	-.914**	-.763*	-.674*	-0.696*	-.845**
	Sig. (2-tailed)	0.001	0.017	0.047	0.037	0.004
	N	9	9	9	9	9

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Only one common correlation was found in both lettuce root and lettuce shoot biomass and that was the concentration of nitrate in the soil. The plant tissue correlation analyses showed nitrate levels having a significant negative correlation with both lettuce root and shoot biomass. In addition to nitrate four other soil properties showed correlations with shoot biomass; EC, ammonium levels, available iron and total potassium. Nitrate and EC each showed to have a significant correlation at 0.01 and ammonium, available iron and total potassium were significant at 0.05. All correlations were negative with EC showing the strongest correlation, followed by nitrate, total iron, available potassium and lastly ammonium.

Table 19 Pearsons Correlations between Lettuce Shoot Biomass and Soil Properties

		EC	**NH_4**	**$N0_3$**	**(M3) Fe Avg**	**(T) K Avg**
(LS) Biomass Avg	Pearson Correlation	-.945**	-.672*	-0.865**	-0.789*	-0.745*
	Sig. (2-tailed)	0.000	0.047	0.003	0.012	0.021
	N	9	9	9	9	9

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The results for nutrient levels in lettuce shoot tissue and biomass were two correlations. Calcium and potassium both had negative correlations with shoot biomass at the 0.05 level; calcium with a 0.758 and potassium with a 0.687 Pearson correlation.

Table 20 Pearsons Correlations between Lettuce Shoot Biomass and Nutrient Concentration in Lettuce Shoot Tissue

		(LS) Ca Avg	**(LS) K Avg**
(LS) Biomass Avg	Pearson Correlation	-0.758*	-0.687*
	Sig. (2-tailed)	0.018	0.041
	N	9	9

*. Correlation is significant at the 0.05 level (2-tailed).

Radish

Soil properties and radish shoot biomass had four correlations between them, three at the 0.05 level and one at the 0.01 level. Total magnesium and radish shoot biomass held a significant correlation at the 0.01 level and total potassium, iron and available manganese were significant at 0.05. All four of the correlations were negative; total magnesium and shoot biomass had the strongest correlation (0.819) followed by available manganese 0.787, total potassium 0.718 and total iron 0.697.

Table 21 Pearsons Correlations between Radish Shoot Biomass and Soil Properties

		(M3) Mn Avg	**(T) Fe Avg**	**(T) K Avg**	**(T) Mg Avg**
(RS) Biomass Avg	Pearson Correlation	-0.787*	-.697*	-.718*	-0.819**
	Sig. (2-tailed)	0.012	0.037	0.029	0.007
	N	9	9	9	9

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Only one correlation between shoot biomass and nutrient concentration in the tissue was found. Sulfur concentration in the tissue had a -0.713 correlation with shoot biomass at the 0.05 level.

Table 22 Pearsons Correlations between Radish Shoot Biomass and Nutrient Concentration in Radish Shoot Tissue

		(RS) S Avg
(RS) Biomass Avg	Pearson Correlation	-0.713*
	Sig. (2-tailed)	0.031
	N	9

*. Correlation is significant at the 0.05 level (2-tailed).

No statistically significant correlations between radish root biomass and soil properties or nutrient concentrations in root tissue were found.

Tomato

For tomato root biomass a negative correlation with total phosphorous in the soil at the 0.05 level was found with a correlation value of 0.683. Ammonium in the soil was not significant at the 0.05 level since the p-value was 0.05 but it is worth noting since it fell right on the cut off limit.

Table 23 Pearsons Correlations between Tomato Root Biomass and Soil Properties

		(T) P Avg	**NH_4**
(TR) Biomass Avg	Pearson Correlation	-.683*	-.666
	Sig. (2-tailed)	0.043	0.05
	N	9	9

*. Correlation is significant at the 0.05 level (2-tailed).

Between concentrations in tomato root tissue and root biomass four significant correlations were found. Copper, iron, manganese and nickel concentrations in the root tissue all had negative correlations with tomato root biomass. Iron and nickel were significant at the 0.01 level and copper and manganese were found to be significant at the 0.05 level. Iron had the strongest correlation value of 0.838 followed by nickel 0.826, copper 0.733 and manganese 0.725.

Table 24 Pearsons Correlations between Tomato Root Biomass and Nutrient Concentration in Tomato Root Tissue

		(TR) Cu Avg	**(TR) Fe Avg**	**(TR) Mn Avg**	**(TR) Ni Avg**
(TR) Biomass Avg	Pearson Correlation	-.733*	-.838**	-.725*	-.826**
	Sig. (2-tailed)	0.025	0.005	0.027	0.006
	N	9	9	9	9

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

There were two significant correlations found between tomato stem biomass. The first correlation found was between the ammonium levels in the soil and the second was with the iron concentration in the tomato leaves. Ammonium levels in the soil had a -0.718 correlation with tomato shoot biomass at a 0.05 level of significance. Iron concentrations in leaf tissue showed a weaker correlation of -0.673 with tomato shoot biomass at a 0.05 significance level.

Table 25 Pearsons Correlations between Tomato Shoot Biomass and Soil Properties

		NH4
(TS) Biomass Avg	Pearson Correlation	-.718*
	Sig. (2-tailed)	0.029
	N	9

*. Correlation is significant at the 0.05 level (2-tailed).

Table 26 Pearsons Correlations between Tomato Shoot Biomass and Nutrient Concentration in Tomato Leaf Tissue

		(TL) Fe Avg
(TL) Biomass Avg	Pearson Correlation	-.673*
	Sig. (2-tailed)	0.047
	N	9

*. Correlation is significant at the 0.05 level (2-tailed).

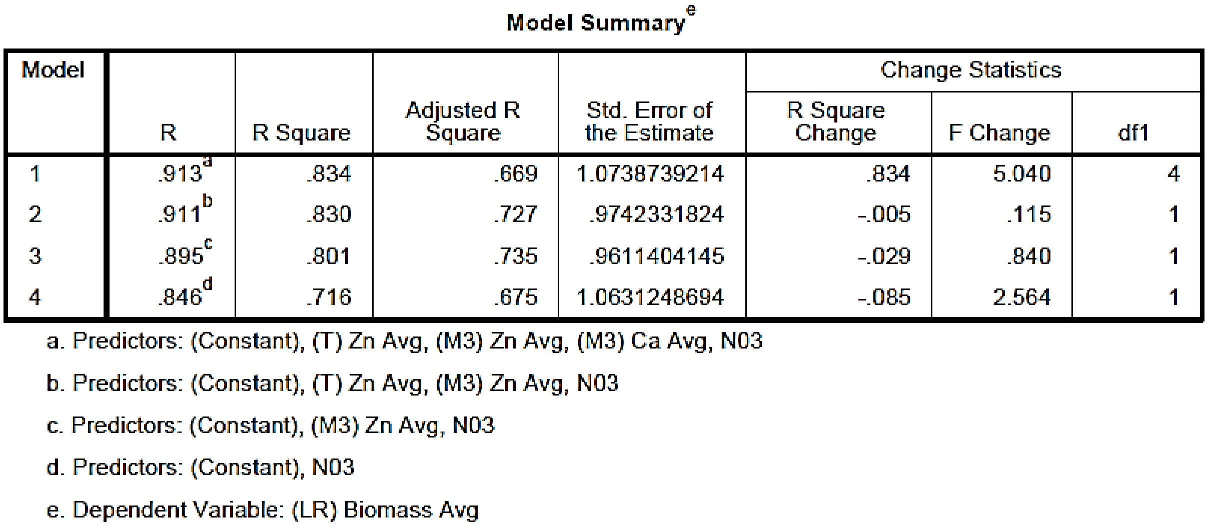
4.11 Backwards Stepwise Regression

Lettuce

Backwards Stepwise Regression determined that calcium concentrations in lettuce roots had the largest correlation out of all the variables that Pearson Correlation modeling found to be significant. The R squared correlation between Lettuce Root biomass and Ca concentrations in the root tissue was 0.836 and significant at the 0.01 level with a p-value of < 0.000.

The soil properties that showed a correlation with lettuce root biomass were total zinc, plant available zinc and calcium and nitrate concentrations. The regression found the nitrate levels to have the strongest correlation with lettuce root biomass with an R squared of 0.716 and to be significant at the 0.01 level with a p-value of 0.002.

Table 27 Backward Stepwise Regression of Significant Nutrient Concentrations in Soil and Lettuce Root Biomass



Model Summary[e]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		
					R Square Change	F Change	df1
1	.913[a]	.834	.669	1.0738739214	.834	5.040	4
2	.911[b]	.830	.727	.9742331824	-.005	.115	1
3	.895[c]	.801	.735	.9611404145	-.029	.840	1
4	.846[d]	.716	.675	1.0631248694	-.085	2.564	1

a. Predictors: (Constant), (T) Zn Avg, (M3) Zn Avg, (M3) Ca Avg, N03

b. Predictors: (Constant), (T) Zn Avg, (M3) Zn Avg, N03

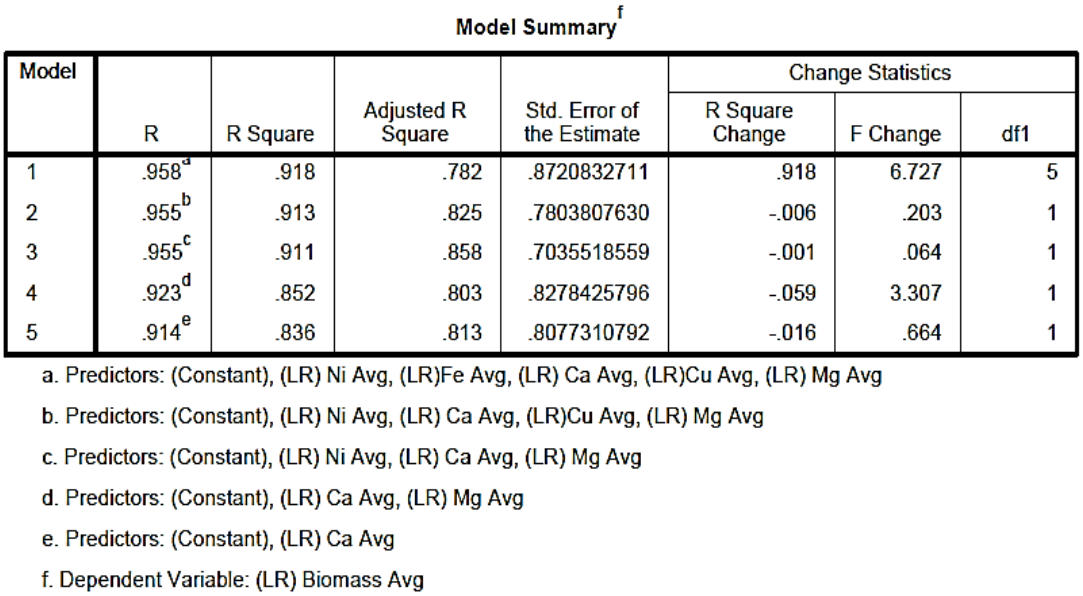
c. Predictors: (Constant), (M3) Zn Avg, N03

d. Predictors: (Constant), N03

e. Dependent Variable: (LR) Biomass Avg

The soil properties which showed to have a correlation with the Lettuce Shoot biomass were input into the Backwards stepwise regression function. The remaining variable in Model 5 was electrical conductivity (EC) which had an R squared value of 0.893. This makes sense since all the significant variables were cations or minerals which tend to be available to plants in the form of cation molecules. Furthermore the first variable excluded from the model was nitrate which in an anion molecule. Between the two significant factors found to negatively impact lettuce shoot biomass it was determined through Backwards Regression that calcium concentrations in the lettuce shoots had a stronger correlation with reducing lettuce shoot biomass.

Table 29 Backward Stepwise Regression of Significant Nutrient Concentration in Lettuce Root Tissue and Lettuce Root Biomass



Model Summary[f]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		
					R Square Change	F Change	df1
1	.958[a]	.918	.782	.8720832711	.918	6.727	5
2	.955[b]	.913	.825	.7803807630	-.006	.203	1
3	.955[c]	.911	.858	.7035518559	-.001	.064	1
4	.923[d]	.852	.803	.8278425796	-.059	3.307	1
5	.914[e]	.836	.813	.8077310792	-.016	.664	1

a. Predictors: (Constant), (LR) Ni Avg, (LR)Fe Avg, (LR) Ca Avg, (LR)Cu Avg, (LR) Mg Avg

b. Predictors: (Constant), (LR) Ni Avg, (LR) Ca Avg, (LR)Cu Avg, (LR) Mg Avg

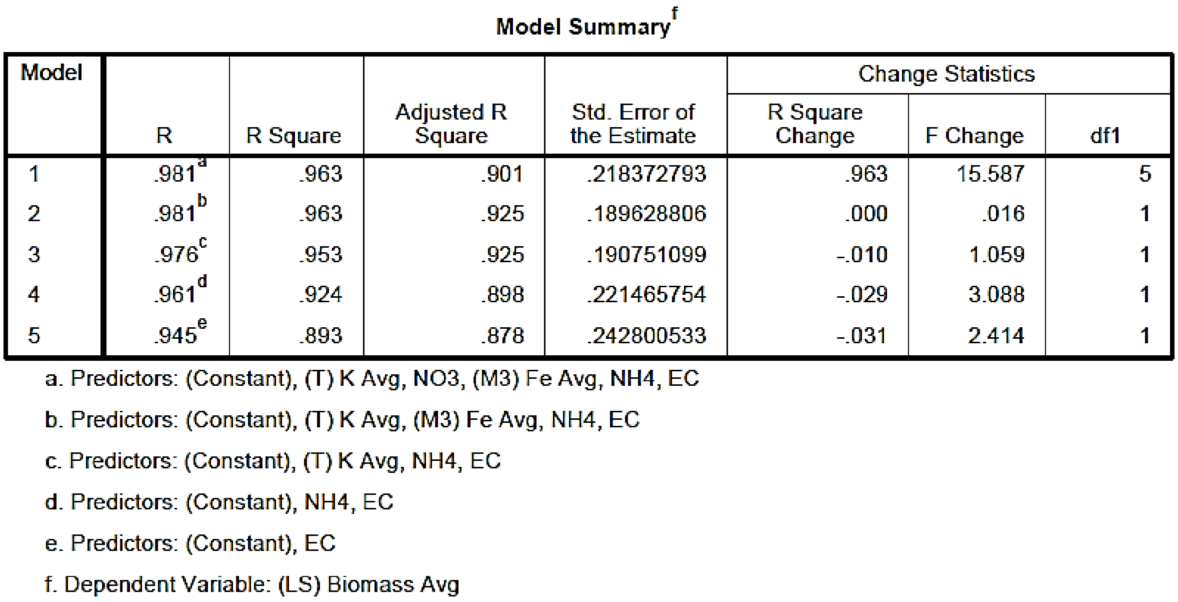
c. Predictors: (Constant), (LR) Ni Avg, (LR) Ca Avg, (LR) Mg Avg

d. Predictors: (Constant), (LR) Ca Avg, (LR) Mg Avg

e. Predictors: (Constant), (LR) Ca Avg

f. Dependent Variable: (LR) Biomass Avg

Table 28 Backward Stepwise Regression of Significant Nutrient Concentrations in Soil and Lettuce Shoot Biomass



Model Summary[f]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		
					R Square Change	F Change	df1
1	.981[a]	.963	.901	.218372793	.963	15.587	5
2	.981[b]	.963	.925	.189628806	.000	.016	1
3	.976[c]	.953	.925	.190751099	-.010	1.059	1
4	.961[d]	.924	.898	.221465754	-.029	3.088	1
5	.945[e]	.893	.878	.242800533	-.031	2.414	1

a. Predictors: (Constant), (T) K Avg, NO3, (M3) Fe Avg, NH4, EC

b. Predictors: (Constant), (T) K Avg, (M3) Fe Avg, NH4, EC

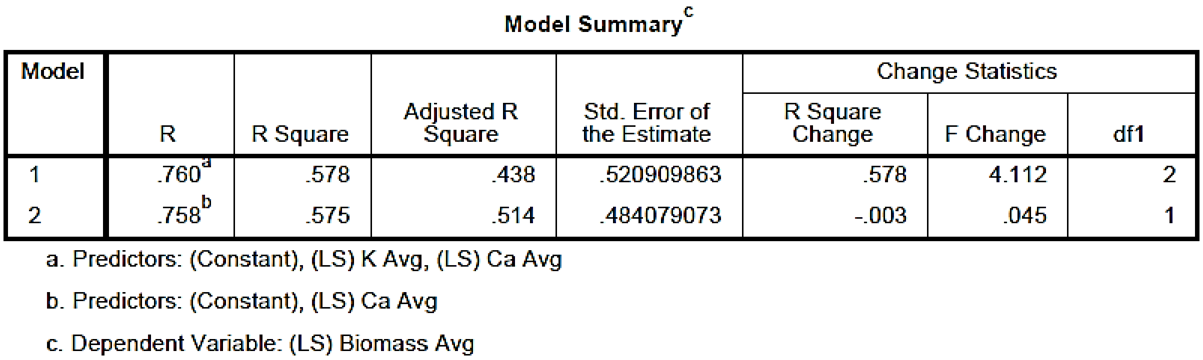
c. Predictors: (Constant), (T) K Avg, NH4, EC

d. Predictors: (Constant), NH4, EC

e. Predictors: (Constant), EC

f. Dependent Variable: (LS) Biomass Avg

Table 30 Backward Stepwise Regression of Significant Nutrient Concentrations in Lettuce Shoot Tissue and Lettuce Shoot Biomass



Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		
					R Square Change	F Change	df1
1	.760[a]	.578	.438	.520909863	.578	4.112	2
2	.758[b]	.575	.514	.484079073	-.003	.045	1

a. Predictors: (Constant), (LS) K Avg, (LS) Ca Avg

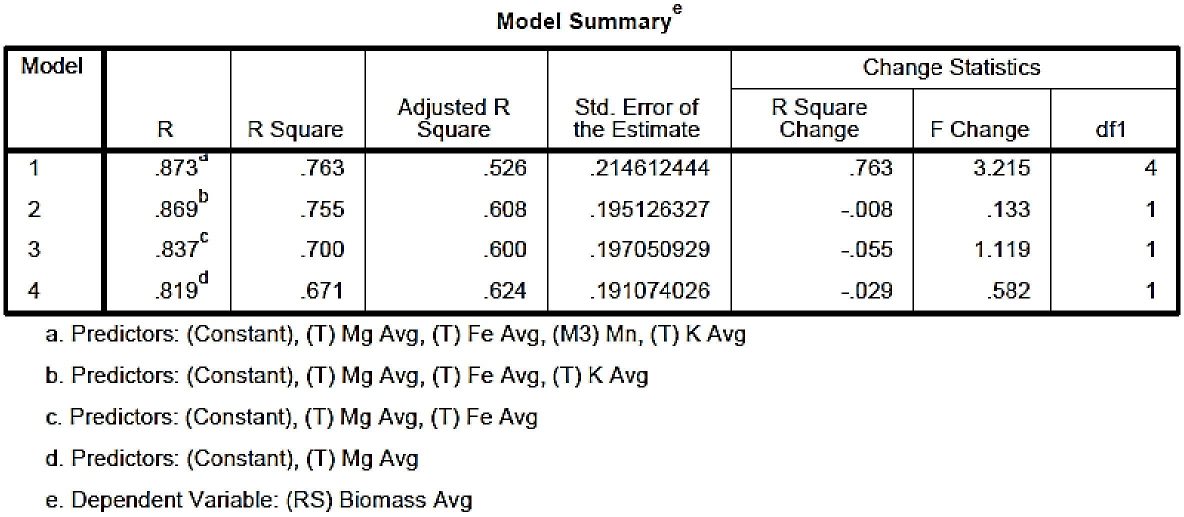
b. Predictors: (Constant), (LS) Ca Avg

c. Dependent Variable: (LS) Biomass Avg

Radish

The Ca concentration as the lone variable had an R squared value of 0.575 and significant at the 0.01 level with a p-value of 0.009. The significant factors found through Pearsons Correlation were input into a Backwards Regression to determine which variable had the most significant impact on Radish Shoot Biomass. The remaining variable in Model 4 was the magnesium concentration in Radish Shoots. The R squared between Mg concentrations and Radish Shoot weight was 0.671 and was determined to be significant at the 0.01 level with a p-value of 0.003.

Table 31 Backward Stepwise Regression of Significant Nutrient Concentrations in Soil Tissue and Radish Shoot Biomass



Model Summary[e]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		
					R Square Change	F Change	df1
1	.873[a]	.763	.526	.214612444	.763	3.215	4
2	.869[b]	.755	.608	.195126327	-.008	.133	1
3	.837[c]	.700	.600	.197050929	-.055	1.119	1
4	.819[d]	.671	.624	.191074026	-.029	.582	1

a. Predictors: (Constant), (T) Mg Avg, (T) Fe Avg, (M3) Mn, (T) K Avg

b. Predictors: (Constant), (T) Mg Avg, (T) Fe Avg, (T) K Avg

c. Predictors: (Constant), (T) Mg Avg, (T) Fe Avg

d. Predictors: (Constant), (T) Mg Avg

e. Dependent Variable: (RS) Biomass Avg

Tomato

The Backwards Regression run for Tomato Root biomass with root tissue concentrations was able to determine the total iron concentration was the variable which had the most significant negative impact on Tomato Root biomass with and R square of 0.701 and was statistically significant at the 0.01 level with a p-value of 0.002.

The Backwards Stepwise Regression for the two variables which showed significant negative correlations with Tomato Root biomass was unable to eliminate either from the model and determine which variable had a greater impact on Tomato Root Biomass. The R squared value of the model with both variables in it was 0.711. Ammonium initially had a correlation of -0.666 and a p-value of .025 while total P had a correlation of -0.683 and a p-value of .021.

Table 32 Backward Stepwise Regression of Significant Nutrient Concentrations in Tomato Root Tissue and Tomato Root Biomass

Model Summary[e]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		
					R Square Change	F Change	df1
1	.908[a]	.824	.649	.10060385052	.824	4.693	4
2	.897[b]	.804	.686	.09508412742	-.020	.466	1
3	.867[c]	.752	.669	.09761322481	-.052	1.323	1
4	.838[d]	.701	.659	.09914977879	-.051	1.222	1

a. Predictors: (Constant), (TR) Ni Avg, (TR) Cu Avg, (TR) Fe Avg, (TR) Mn Avg

b. Predictors: (Constant), (TR) Ni Avg, (TR) Cu Avg, (TR) Fe Avg

c. Predictors: (Constant), (TR) Cu Avg, (TR) Fe Avg

d. Predictors: (Constant), (TR) Fe Avg

e. Dependent Variable: (TR) Biomass Avg

Table 33 Backward Stepwise Regression of Significant Nutrient Concentrations in Soil and Tomato Root Biomass

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		
					R Square Change	F Change	df1
1	.843[a]	.711	.615	.10533181201	.711	7.387	2

a. Predictors: (Constant), (T) P Avg, NH4

b. Dependent Variable: (TR) Biomass Avg

4.12 ANOVA

Analysis of Variance (ANOVA) was conducted for the plants to determine if there was any significant differences between the amendment/treatment combinations and the control. This was done by comparing dry biomass of the plants with the nominal group or treatment variable. A homogeneity of variance (HoV) test was conducted with the initial ANOVA analysis so an appropriate Post HOC test could be selected based on whether or not the HoV assumption was violated. If the assumption was not violated (the reported value was ≥ 0.05) then the Tukey Post Hoc test was used but if the assumption was violated (< 0.05) then the Games-Howell test was used.

The Analysis of Variance (ANOVA) for the average Biomass of lettuce shoots between treatments showed a statistically significant difference between four of the amendment/biological treatments and the control. All treatments had a lower mean biomass than the lettuce grown in the control soil. The control had an average dry biomass of 2.559 grams per plant. The Biosolid+Fungus treatment had the greatest mean biomass difference from the control and an average of 0.226 g/plant a mean difference of 2.333 g less per plant on average and was statistically significant at a 0.01 level with a p-value of 0.001.

The Biosolid+Bacteria Mix and Biosolid treatments also showed a statistical significance difference at the 0.01 level with p-values of 0.002 and 0.004 respectively. The Biosolid+Bacteria Mix treatment had a mean biomass weight of 1.140 g/plant a mean difference of - 1.419 g compared to the control and the Biosolid amendment had an average biomass weight of 1.240 g/plant a mean difference of 1.320 g less than the control. At the 0.05 level the Compost+Fungus treatment showed a significant decrease in the biomass with a p-value of 0.027 and a mean biomass of 1.358 g/plant a decrease of 1.202 g/plant in comparison to the control.

Lettuce

Table 34 Post Hoc Test for ANOVA of Lettuce Shoot Biomass between Control and Treatments.

Multiple Comparisons				
(LS) Biomass Games-Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	0.2103	0.15	0.845
	Fungus	0.6484	0.17	0.093
	Biosolid	1.3195*	0.18	0.004
	Biosolid+Bacteria Mix	1.4191*	0.15	0.002
	Biosolid+Fungus	2.3336*	0.13	0.001
	Compost	0.9879	0.40	0.432
	Compost+Bacteria Mix	0.8756	0.36	0.449
	Compost+Fungus	1.2015*	0.22	0.027

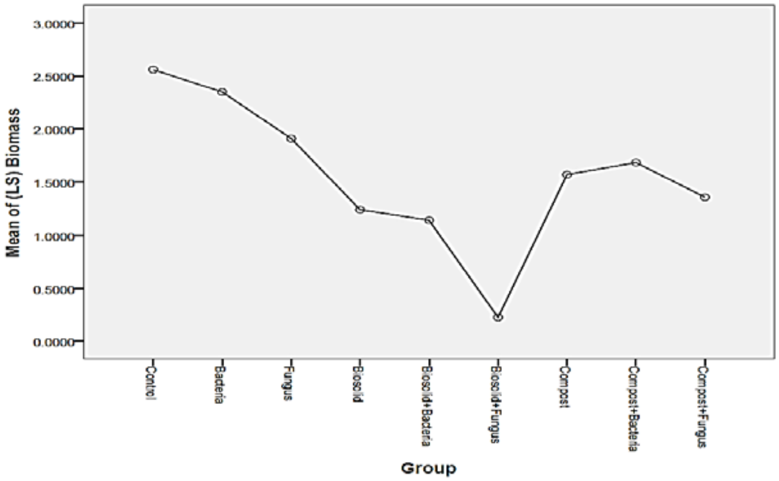


Figure 9 Mean Lettuce Shoot Biomass per Treatment

The ANOVA analysis of the plant available nutrients (Mehlich III) in the soil found several significant results for five nutrients. There was statistically significant differences found in the levels of calcium, potassium, magnesium, phosphorous, and sulfur for certain treatments in comparison with the control. A significant difference at the 0.01 level was found between the Control soil and the Biosolid+Bacteria Mix amendment with a p-value of 0.005. The available calcium level was found to have a mean difference of 1786.25 mg/kg greater than the Control soil.

Several treatments were found to have significantly higher potassium levels above the available levels in the Control. Biosolid and Biosolid+Bacteria Mix had more available potassium at a 0.05 level as they had p-values of 0.016 and 0.018 respectively. Biosolid had a mean difference of 48.49 mg/kg greater and Biosolid+Bacteria Mix had 75.55 mg/kg greater than the Control. At a significance level of 0.01 the Compost+Bacteria Mix (p-value 0.001) was found to have a concentration of 148.38 mg/kg greater than the Control.

Table 35 Post Hoc Test for ANOVA of Mehlich III, Ca (Top) K (Bottom) between Control and Treatments

(M3) Ca Games-Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	14.338	29.1	0.999
	Fungus	-16.007	59.6	1.000
	Biosolid	-2.70E+03	163.3	0.094
	Biosolid+Bacteria Mix	-1786.254*	25.8	0.005
	Biosolid+Fungus	-1.89E+03	345.3	0.295
	Compost	-893.918	86.6	0.130
	Compost+Bacteria Mix	-1.24E+03	98.8	0.110
	Compost+Fungus	-1.08E+03	126.4	0.177

(M3) K Games_Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	-4.846	0.83	0.278
	Fungus	-6.631	0.91	0.151
	Biosolid	-48.489*	0.87	0.016
	Biosolid+Bacteria Mix	-75.548*	0.83	0.018
	Biosolid+Fungus	-106.278	4.00	0.051
	Compost	-108.852	6.36	0.091
	Compost+Bacteria Mix	-148.383*	1.45	0.001
	Compost+Fungus	-144.132*	4.84	0.048

For magnesium the Biosolid+Bacteria Mix amendment was found to have a greater available concentration of 54.11 mg/kg than the Control at the 0.01 significance level with a p-value of 0.004. The Biosolid (p-value 0.017) and Compost+Bacteria Mix (p-value 0.044) treatments also had greater levels of magnesium available with mean differences of 81.91 and 192.69 mg/kg over the Control level. The concentration of available phosphorous in the Compost+Bacteria Mix amendment was decreased from the Control by a mean difference of 21.29 mg/kg less at a significance level of 0.01 with a p-value of 0.000.

Table 36 Post Hoc Test for ANOVA of Mehlich III, Mg (Top) P (Bottom) between Control and Treatments

(M3) Mg Games-Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	1.628	2.64	0.992
	Fungus	-0.588	3.94	1.000
	Biosolid	-81.912*	1.54	0.017
	Biosolid+Bacteria Mix	-54.115*	0.89	0.004
	Biosolid+Fungus	-59.058	7.81	0.216
	Compost	-158.754	14.88	0.155
	Compost+Bacteria Mix	-192.692*	5.26	0.044
	Compost+Fungus	-176.955	12.46	0.117

(M3) P Games-Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	6.683	5.29	0.872
	Fungus	-2.038	9.23	1.000
	Biosolid	-6.710	4.20	0.785
	Biosolid+Bacteria Mix	-9.788	1.78	0.296
	Biosolid+Fungus	0.587	9.69	1.000
	Compost	5.506	0.63	0.185
	Compost+Bacteria Mix	21.293*	0.10	0.000
	Compost+Fungus	22.159	3.63	0.268

Available sulfur levels had two amendment/treatment combinations differ significantly from the Control which had a mean concentration of 64.6 mg/kg. Biosolid+Bacteria Mix (88.95 mg/kg) and, Compost+Bacteria Mix (99.86) differed significantly at the 0.05 level. Total calcium concentration in the Control that lettuce was grown in had a mean of 4,962 mg/kg. The Compost+Fungus had a mean concentration of 12,641 mg/kg and was significantly different at the 0.05 level.

Table 37 Post Hoc Test for ANOVA of Mehlich III S (Top) and Total Ca (Bottom) between Control and Treatments

(M3) S Games-Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	-10.056	2.11	0.299
	Fungus	1.596	3.96	0.999
	Biosolid	-57.840	3.94	0.105
	Biosolid+Bacteria Mix	-24.332*	0.63	0.024
	Biosolid+Fungus	-20.086	5.70	0.439
	Compost	-29.551	6.83	0.366
	Compost+Bacteria Mix	-35.240*	0.60	0.027
	Compost+Fungus	-32.791	3.44	0.160

(T) Ca Games-Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	757	534	0.831
	Fungus	995	642	0.791
	Biosolid	-2084	981	0.618
	Biosolid+Bacteria Mix	-2356	1329	0.728
	Biosolid+Fungus	-1495	1786	0.968
	Compost	-2923	936	0.395
	Compost+Bacteria Mix	-8652	5163	0.764
	Compost+Fungus	-7679*	726	0.042

Radish

The ANOVA analysis of the radish root biomass showed only one statistically significant difference between the control and all other treatments. The radish roots grown in the control soil had an average dry biomass of 0.937 g/plant. The

Biosolid+Bacteria Mix was found to show significant difference from the Control at the 0.01 level with a p-value of 0.000 and had an average dry biomass of 1.729 g/plant a positive mean difference of .793 g/plant.

Table 38 Post Hoc Test for ANOVA of Radish Root Biomass between Control and Treatments.

(RR) Biomass Tukey HSD				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	0.126	0.15	0.995
	Fungus	0.501	0.15	0.054
	Biosolid	0.332	0.15	0.432
	Biosolid+Bacteria Mix	-0.793*	0.15	0.000
	Biosolid+Fungus	0.045	0.15	1.000
	Compost	0.045	0.15	1.000
	Compost+Bacteria Mix	0.252	0.15	0.755
	Compost+Fungus	0.174	0.15	0.960

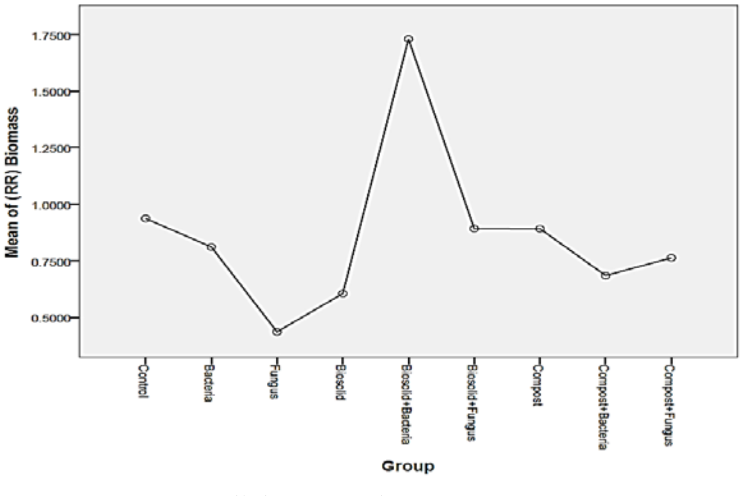


Figure 10 Mean Radish Root Biomass per Treatment

The statistically significant results found by the ANOVA test for plant available nutrients in the soil are displayed below. Statistically significant differences between the Control and amendment and or treatment combinations were found for four nutrients; calcium, potassium, magnesium and sulfur. For Ca the Biosolid, Biosolid+Fungus, Compost and Compost+Fungus had significantly different plant available concentration levels at the significance level of 0.05. The average concentration of Ca found in the Control was 1599 mg/kg. The concentrations for the amendment/treatments listed in the order above was 2859, 3166, 2074, and 2395 mg/kg.

Potassium concentrations differed from the Control (50.3) at statistically significant levels in Biosolid (87.9), Biosolid+Fungus (83.6), Compost (146), Compost+Bacteria Mix (135.5) and Compost+Fungus (88.7). Biosolid and Compost+Bacteria Mix were significant at the 0.01 level and all others were at the 0.05 level.

Table 39 Hoc Test for ANOVA of Mehlich III, Ca (Top) K (Bottom) between Control and Treatments

(M3) Ca Games-Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	-73.9	49.2	0.808
	Fungus	-28.7	35.8	0.974
	Biosolid	-1259.9*	32.4	0.021
	Biosolid+Bacteria Mix	-1118.2	82.9	0.116
	Biosolid+Fungus	-1566.6*	28.4	0.010
	Compost	-474.7*	27.4	0.046
	Compost+Bacteria Mix	-765.0	174.3	0.363
	Compost+Fungus	-795.9*	23.9	0.013

(M3) K Games-Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	-1.26	2.21	0.995
	Fungus	0.44	1.05	0.999
	Biosolid	-37.59*	0.73	0.002
	Biosolid+Bacteria Mix	-17.51	2.36	0.199
	Biosolid+Fungus	-33.30*	0.51	0.025
	Compost	-75.39*	1.41	0.013
	Compost+Bacteria Mix	-95.64*	0.78	0.000
	Compost+Fungus	-85.16*	1.64	0.017

Plant available soil concentrations for magnesium were significantly higher in the Biosolid+Fungus and Compost+Fungus combinations than they were in the Control. The Control had a mean concentration of 160.2 mg/kg while Biosolid+Fungus had a mean concentration of 196.9 and significant at 0.05; Compost+Fungus, a 288.7 mean concentration was significant at 0.01.

Sulfur concentrations for Biosolid 74.8, Biosolid+Fungus 84, Compost 92.3 and Compost+Fungus 83.2 were determined to be significantly lower than the mean Control concentration of 50.7 mg/kg. Compost and Compost+Fungus were significantly different at the 0.01 level while Biosolid and Biosolid+Fungus at the 0.05 level.

Table 40 Post Hoc Test for ANOVA of Mehlich III, Mg (Top) S (Bottom) between Control and Treatments

(M3) Mg Games-Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	-5.69	6.58	0.961
	Fungus	-7.86	1.81	0.287
	Biosolid	-28.44	10.15	0.535
	Biosolid+Bacteria Mix	-31.95	3.22	0.141
	Biosolid+Fungus	-36.42*	1.36	0.01
	Compost	-95.08	3.80	0.055
	Compost+Bacteria Mix	-148.66	6.44	0.068
	Compost+Fungus	-128.57*	1.66	0.004

(M3) S Games-Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	-4.69	1.75	0.502
	Fungus	-14.83	2.10	0.173
	Biosolid	-24.16*	0.84	0.020
	Biosolid+Bacteria Mix	-13.42	3.28	0.365
	Biosolid+Fungus	-33.31*	1.88	0.047
	Compost	-41.61*	0.89	0.005
	Compost+Bacteria Mix	-49.30	2.60	0.061
	Compost+Fungus	-32.52*	0.90	0.007

Tomato

ANOVA analysis amendment/treatment compared with tomato shoot biomasses showed six significant correlations between the Control and different amendment and or microbial treatments groups. Three treatments, Fungus, Biosolid+Bacteria Mix and Biosolid+Fungus showed statistically significant differences at a level of 0.01. The Bacteria Mix, Compost+Bacteria Mix and Compost+Fungus were significantly different at a level of 0.05 significance. The Control tomato plants had a mean weight of 2.867 grams/plant. Fungus, Biosolid+Bacteria Mix and Biosolid+Fungus had mean weights of 1.076, 1.143 and 0.590 grams/plant respectively. The only amendment, Biosolid that had a higher mean average biomass than the Control was not statistically different.

Table 41 Post Hoc Test for ANOVA of Tomato Shoot Biomass between Control and Treatments.

(TS) Biomass Games-Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	1.310*	0.15	0.015
	Fungus	1.790*	0.22	0.003
	Biosolid	-0.585	0.22	0.307
	Biosolid+Bacteria Mix	1.724*	0.22	0.003
	Biosolid+Fungus	2.277*	0.17	0.001
	Compost	0.4297	0.52	0.987
	Compost+Bacteria Mix	0.921*	0.16	0.033
	Compost+Fungus	0.845*	0.18	0.048

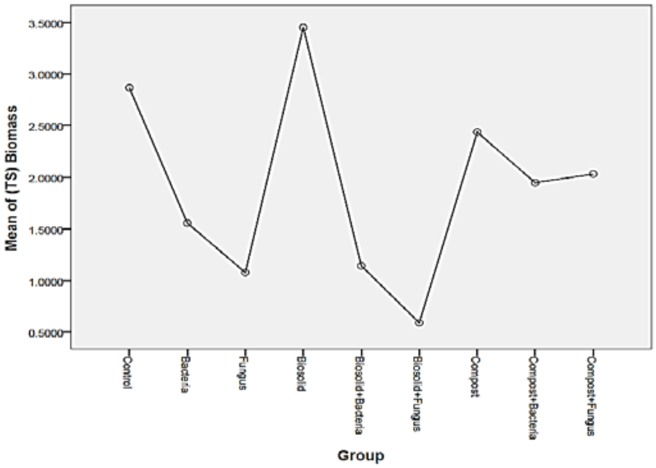


Figure 11 Mean Tomato Shoot Biomass per Treatment

For plant available calcium the Control had a mean concentration of 1333 mg/kg. Three amendment and microbial treatment combinations had higher available levels than the Control at a statistically significant level. Biosolid+Bacteria Mix had a mean calcium concentration of 2299 mg/kg and Compost+Fungus a mean of 2272 mg/kg; both were significant at 0.05. Biosolid+Fungus had a mean concentration of 2407 mg/kg and was significantly different from the Control at the 0.01 level.

Available iron showed the Control as having a mean concentration of 189.4 mg/kg. There were six amendment and treatments combinations that were statistically different at the 0.05 significance level. All significant amendment and or treatment combinations had lower concentrations than the Control. The combinations with mean concentrations were; Biosolid 120.7, Biosolid+Bacteria Mix 116.9, Biosolid+Fungus 116.4, Compost 139.4, Compost+Bacteria Mix 132 and Compost+Fungus 140.5 mg/kg.

Table 42 Post Hoc Test for ANOVA of Mehlich III, Ca (Top) Fe (Bottom) between Control and Treatments

(M3) Ca Games-Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	13.9	33.58	0.999
	Fungus	-31.2	6.40	0.252
	Biosolid	-840.3	31.09	0.060
	Biosolid+Bacteria Mix	-966.0*	26.54	0.044
	Biosolid+Fungus	-1074.0*	7.81	0.004
	Compost	-804.5	52.15	0.107
	Compost+Bacteria Mix	-1016.7	40.02	0.065
	Compost+Fungus	-939.8*	21.51	0.035

(M3) Fe Games-Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	11.97	2.93	0.328
	Fungus	14.93	5.08	0.427
	Biosolid	68.69*	3.59	0.014
	Biosolid+Bacteria Mix	72.52*	3.92	0.014
	Biosolid+Fungus	73.05*	3.51	0.013
	Compost	49.48*	3.64	0.026
	Compost+Bacteria Mix	57.44*	2.94	0.045
	Compost+Fungus	48.93*	3.96	0.031

Amendment and or treatment combinations for available K that were significantly different than the Control which had a concentration of 30.88 mg/kg were Bacteria Mix 47.18 mg/kg, Biosolid 54.36 mg/kg, Biosolid+Bacteria Mix 102.27 mg/kg, Biosolid+Fungus 111.73 mg/kg, Compost+Bacteria Mix 101.13 mg/kg and Compost+Fungus 92.75 mg/kg. All had significantly higher concentrations than the

Control at the 0.05 level. Biosolid+Fungus had the highest concentration and a mean difference of 80.85 mg/kg greater than the Control concnetration.

Available Mg showed only two amendment and treatment combinations which were statistically significant at 0.05 compared to the Control. These were Biosolid+Bacteria Mix which had a mean concentration of 157.6 mg/kg and Biosolid+Fungus, mean concentration 163.1 mg/kg. The Controls mean concentration was 138.16 mg/kg.

Table 43 Post Hoc Test for ANOVA of Mehlich III, Mg (Top) K (Bottom) between Control and Treatments

(M3) K Games-Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	-16.31*	1.07	0.021
	Fungus	-12.38	0.74	0.074
	Biosolid	-23.49*	1.28	0.022
	Biosolid+Bacteria Mix	-71.39*	1.59	0.010
	Biosolid+Fungus	-80.85*	2.09	0.022
	Compost	-60.19	4.87	0.126
	Compost+Bacteria Mix	-70.25*	2.29	0.032
	Compost+Fungus	-61.88*	2.43	0.043

(M3) Mg Games-Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	1.691	1.65	0.937
	Fungus	-1.814	1.67	0.923
	Biosolid	-3.967	1.09	0.300
	Biosolid+Bacteria Mix	-19.46*	0.98	0.012
	Biosolid+Fungus	-24.96*	1.58	0.049
	Compost	-115.115	9.15	0.130
	Compost+Bacteria Mix	-145.317	6.30	0.069
	Compost+Fungus	-133.836	5.80	0.068

Available Mn had only one amendment, Biosolid with a concentration of 58.4 mg/kg that had a significant statistical difference at the 0.05 level from the Control concentration of 90.7 mg/kg. Phosphorous concentration only had one significant difference at 0.05 from the Control concentration mean of 299.18 mg/kg which was Biosolid+Fungus with a mean of 278.4 mg/kg.

Table 44 Post Hoc Test for ANOVA of Mehlich III, Mn (Top) P (Bottom) between Control and Treatments

(M3) Mn Games-Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	4.55	2.63	0.737
	Fungus	-14.61	1.51	0.056
	Biosolid	32.30*	2.30	0.040
	Biosolid+Bacteria Mix	31.58	1.21	0.055
	Biosolid+Fungus	35.52	1.21	0.051
	Compost	-1.22	2.49	0.999
	Compost+Bacteria Mix	-3.01	4.92	0.992
	Compost+Fungus	-5.65	3.93	0.826

(M3) P Games-Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	-2.52	14.21	1.00
	Fungus	1.55	0.54	0.454
	Biosolid	16.52	1.40	0.126
	Biosolid+Bacteria Mix	23.30	8.17	0.529
	Biosolid+Fungus	20.74*	0.56	0.011
	Compost	18.61	7.22	0.573
	Compost+Bacteria Mix	40.30	4.39	0.179
	Compost+Fungus	25.83*	0.76	0.025

Available S in the Compost which had a concentration of 102.37 mg/kg was significant higher than the Control concentration of 56.92 mg/kg at the significance level of 0.05.

Table 45 Post Hoc Test for ANOVA of Mehlich III S between Control and Treatments

(M3) S Games-Howell				
(I) Group	(J) Group	Mean Difference (I- J)	Std. Error	Sig.
Control	Bacteria Mix	-0.76	3.66	1.000
	Fungus	-14.71	2.74	0.301
	Biosolid	-4.60	3.29	0.839
	Biosolid+Bacteria Mix	-27.22	7.61	0.384
	Biosolid+Fungus	-22.04	5.61	0.305
	Compost	-45.46*	3.11	0.045
	Compost+Bacteria Mix	-45.53	6.91	0.177
	Compost+Fungus	-29.52	2.74	0.151

4.13 General Discussion

The data showed all but one Pearson correlation between plant biomass and nutrient concentrations in soil and plant tissue were negative; this was the prevailing trend found in the study. The single positive correlation was between lettuce root biomass and plant available zinc in soil. The prevailing trend found in all crop types between increasing nutrient concentrations and reduction in plant biomass indicates stress to plants and possibly toxicity due to nutrient overabundance. This also indicates a sufficient level of nutrients were available to the crops in the Control soil. In general, as nutrient levels increased in the soil and accumulated in the plant tissues, a reduction in plant biomass was observed for all three types of crop.

Furthermore, the small number of correlations found relative to the number of variables tested was not expected. One factor that could have led to a reduction in the number of significant correlations observed was variability in nutrient concentrations in plant tissue and soils (Mehlich III). The variability in concentration of nutrients for plants and soils is provided in Appendix A.

Instead of testing soil available nutrients in duplicate, triplicate testing may have been able to establish more trends, resulting in more statistically significant findings and a larger number of correlations. Since soils tend to be heterogenous and significant variations can occur in small quantities, resulting in larger standard deviations and standard errors which can affect the means of soil parameters. The same can be said for the variation seen in crops. Typically the Control tended to have the smallest correlation of variation (CV) for Mehlich III and plant tissue nutrients while the amendments with and without microbial treatments tended to have higher CVs. ANOVA statistical analysis could be conducted on CV to further investigate variability in treatments.

The microbial plating results showed Biosolid to have the greatest percentage of plate coverage for bacterial growth on TSA media followed by the Biosolid+Bacteria Mix and Biosolid+Fungus for all three crops. Biosolid being a remnant of fecal material has the capacity to introduce a source of bacteria and an increase in not unexpected. The Fungus treatment had the lowest percentage of plate coverage using TSA followed by the Conrol for all three crops. An introduction of symbiotic fungus to the rhizospere can increase the abundance of AMF growth and in turn reduce the bacteria community through competition.

The microbial plating for fungal observation on SDA resulted in the Compost yielding the highest percentage of plate coverage for all three crops. An increase in organic material for instance can promote fungal growth as fungus can enhance the decomposition rate of organic material (Leigh et al. 2011). The Compost amendment had one of highest percentages of OM which could have led to the propagation of fungus.

The Control for the tomato crop, Bacteria Mix for the radish and Biosoild+Bacteria Mix for the lettuce had the lowest percentage of plate coverage on SDA. Microbial analysis for fungus using SDA showed greater variation in percentage of plate coverage between crop species than the bacteria analysis did between crops using the TSA.

The results can be used to compare treatments against each other but not as a quantitative analysis of soil microbial community populations. The results do however demonstrate both amendment and or microbial additions as well as crop type influenced the microbial soil community diversity.

Competition and fluctuation regularly takes place in the microbial soil community. Communities of fungi and bacteria can affect one another as soil conditions change. Bacterial proliferation on the other hand can suppress fungal growth in instances when conditions are more favorable or root exudates dictate a shift in the microbial community towards bacterial growth promotion (Wardle 2006).

The influence of the above ground conditions has a large impact on the soil microbial community as well. Soils in which host monocultures of plants, support very different soil organism diversity as the plants or crops impose their influential contribution to the soil microbial make-up (Wardle 2006). This is in part due to how plants cycle organic matter of different qualities back to the soil influencing the trophic levels in the soil and restricting the food web.

Based on mean average biomass of all three crops grown in the Control soil the soil quality appears well suited for crop growth. Overall soil health was found to be very good for crop success as none of the plants grew poorly in the Control soil and some of the highest overall crop biomass. Another area which could have led to some of the amendments and or microbial treatments doing poorly was the growth containers size and lack of drainage. Since excess nutrient concentrations couldn't leach from the rhizospere, conducting similar tests with larger containers or a drainage system which collects any water loss could help alleviate the excess nutrient loads to the plants while still collecting excess water for analysis.

4.14 Future Research

This study serves as a basis for future research in several ways. Depending upon the area of focus, conducting a similar experiment at a different location could produce different results as the Oak Hill soil is well suited for plant growth. Urban locations with lower amounts of organic matter or diminished nutrient pools could benefit from the amendment and or treatments utilized in this study and increase yields.

Since the crops were grown in containers without drainage for testing purposes, limitations could have occurred. Since there wasn't drainage from the containers excess nutrient accumulation in the rhizosphere that would have been reduced in a field experiment could have reduced plant growth. Also this study used biomass as a determining factor for measuring success of the crops which can be but is not always a measure of yield, especially with fruit bearing crops like tomatoes. Tomatoes were not produced in this study and shoot biomass can not be used to directly measure yield from tomato crops.

The microbial aspect could be studied more in depth to try to establish the influence that microbial abundance and makeup play regarding nutrient uptake and plant growth. Testing for quantity and population diversity in the soil could be conducted throughout the growing season to try and establish roles and influences of the microbial community. This could help determine if shifts in the microbial community take place during the growth phases of the plants.

Another direction future studies could build from this one is how amendments and treatments influence the crops nutritional content. If you have certain combinations which show statistically similar success in crop yields, but significant differences of nutritional concentrations in the edible portions of crops; amendment and treatment options could be selected with an aim towards increasing vitamins and minerals like potassium, magnesium or zinc concentrations.

Chapter 5 Conclusion

This study found the following correlations. Calcium concentrations in lettuce roots and shoots were determined to have the strongest correlation on reducing root development. Available nitrogen forms, nitrate for roots and ammonium concentrations for shoots showed to have the strongest correlations with reducing shoot biomass. Lettuce performed best in the Control, Bacteria Mix, Fungus, Compost, Compost+Bacteria Mix and worse in Biosolid, Biosolid+Bacteria Mix, Biosolid+Fungus and Compost+Fungus. Total magnesium concentrations in radish amendment and or microbial treatment were found to have the largest effect on reducing shoot biomass. Sulfur concentrations in the radish shoots was the only correlation found in plant tissue.

No correlations between root biomass and soil properties or tissue concentrations were found.

Radish plants grew best in the Biosolid+Bacteria Mix and worse in all other combinations. No other amendment and or microbial treatment displayed significantly worse results. Iron concentrations in tomato roots and ammonium concentrations in soils showed the strongest negative correlations with root and shoot growth. Tomato plants grew the best in Biosolid, Compost and Control amendments and worse in the Bacteria Mix, Fungus, Biosolid+Bacteria Mix, Biosolid+Fungus, Compost+Bacteria Mix and Compost+Fungus amendments and microbial treatments.

Other factors that could impact plant growth that couldn't be analyzed statistically were competition from microbial populations added through the compost and biosolids and could have been factors that influenced plant growth. The hypotheses stating that improving soil conditions with amendments, microbial treatments, or microbial treatments in combination with amendments, was rejected. Although there was evidence supporting that the amendments and microbial treatments did increase certain nutrient availability and uptake in plant tissue, this did not result in an increase in plant growth in all plant species.

The results from this study lead to the recommendation that the Oak Hill field site soil does not need additional soil amendment or treatment as the soil is sufficient for crop growth. If the Oak Hill community wishes to establish an urban garden at the site it can be accomplished successfully in this current state.

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Appendix A: Soil Mehlich III and Plant Tissue Analyses

Table 46 Nutrient Concentrations in Tomato Roots

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(TR) Biomass	(TR) Ca	(TR) Ca Avg	(TR) Ca Stdv	(TR) Ca CV	(TR) Cu	(TR) Cu Avg	(TR) Cu Stdv	(TR) Cu CV	(TR) Fe	(TR) Fe Avg	(TR) Fe Stdv	(TR) Fe CV
Tomato	Root	Control	1	24.8	0.447	5443	5346	299	0.06	37.7	30.38	6.23	0.20	2826	2207	623	0.28
Tomato	Root	Control	2	20.0	0.5866	5485				27.7				2641			
Tomato	Root	Control	3	19.9	0.5885	5554				32.7				1540			
Tomato	Root	Control	4	19.9	0.5535	4903				23.3				1821			
Tomato	Root	Bacteria	1	31.3	0.368	2608	2848	351	0.12	14.4	17.55	2.11	0.12	2446	2767	674	0.24
Tomato	Root	Bacteria	2	40.0	0.291	3359				18.1				2020			
Tomato	Root	Bacteria	3	34.0	0.3472	2795				18.8				3558			
Tomato	Root	Bacteria	4	35.6	0.3292	2630				18.8				3044			
Tomato	Root	Fungus	1	50.8	0.2385	6265	7181	700	0.10	39.8	41.54	2.64	0.06	4848	5173	537	0.10
Tomato	Root	Fungus	2	98.2	0.1145	7867				40.2				5973			
Tomato	Root	Fungus	3	42.2	0.284	7554				45.5				4880			
Tomato	Root	Fungus	4	96.8	0.1292	7037				40.7				4991			
Tomato	Root	Biosolid	1	26.6	0.3895	14207	12451	1664	0.13	37.1	27.92	6.13	0.22	2984	3819	726	0.19
Tomato	Root	Biosolid	2	23.6	0.4472	12770				24.3				3482			
Tomato	Root	Biosolid	3	19.9	0.5353	12630				25.8				4199			
Tomato	Root	Biosolid	4	20.2	0.5666	10196				24.5				4610			
Tomato	Root	Biosolid+Bacteria	1	48.3	0.264	13300	18706	5551	0.30	30.8	46.05	17.07	0.37	4266	5130	630	0.12
Tomato	Root	Biosolid+Bacteria	2	43.4	0.2698	14538				40.6				5397			
Tomato	Root	Biosolid+Bacteria	3	70.4	0.154	23585				42.4				5742			
Tomato	Root	Biosolid+Bacteria	4	114.2	0.0891	23402				70.5				5118			
Tomato	Root	Biosolid+Fungus	1&2 Cp	108.9	0.1	28780	25686	3835	0.15	55.2	71.23	15.36	0.22	4100	8548	4991	0.58
Tomato	Root	Biosolid+Fungus	3	74.7	0.1592	26883				72.8				13946			
Tomato	Root	Biosolid+Fungus	4	103.4	0.1037	21396				85.8				7598			
Tomato	Root	Compost	1	20.0	0.5944	7603	7756	2126	0.27	22.0	17.40	5.82	0.33	858	1415	482	0.34
Tomato	Root	Compost	2	208.3	0.0542	10808				8.9				1235			
Tomato	Root	Compost	3	19.9	0.5836	6393				19.9				1985			
Tomato	Root	Compost	4	20.0	0.6509	6221				18.7				1584			
Tomato	Root	Compost+Bacteria	1	24.0	0.4445	8266	9781	1321	0.14	36.4	39.47	9.97	0.25	2886	4063	1786	0.44
Tomato	Root	Compost+Bacteria	2		0.4907												
Tomato	Root	Compost+Bacteria	3	38.8	0.3196	10388				31.4				6118			
Tomato	Root	Compost+Bacteria	4	26.0	0.442	10690				50.6				3184			
Tomato	Root	Compost+Fungus	1	24.3	0.4794	4308	3984	280	0.07	19.2	16.89	2.07	0.12	2077	1984	348	0.18
Tomato	Root	Compost+Fungus	2	29.4	0.3708	3685				16.5				1819			
Tomato	Root	Compost+Fungus	3	32.7	0.3577	4114				17.6				1616			
Tomato	Root	Compost+Fungus	4	29.3	0.3833	3831				14.3				2423			

Table 47 Nutrient Concentrations in Tomato Roots Continued 1

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(TR) Biomass	(TR) K	(TR) K Avg	(TR) K Stdv	(TR) K CV	(TR) Mg	(TR) Mg Avg	(TR) Mg Stdv	(TR) Mg CV	(TR) Mn	(TR) Mn Avg	(TR) Mn Stdv	(TR) Mn CV
Tomato	Root	Control	1	24.8	0.447	7673	6895	930	0.13	3141	3185	317	0.10	188	179	21.94	0.12
Tomato	Root	Control	2	20.0	0.5866	5840				2893				185			
Tomato	Root	Control	3	19.9	0.5885	7680				3634				197			
Tomato	Root	Control	4	19.9	0.5535	6387				3072				147			
Tomato	Root	Bacteria	1	31.3	0.368	7979	9120	2234	0.24	1952	2092	191	0.09	88	96	11.69	0.12
Tomato	Root	Bacteria	2	40.0	0.291	12466				2363				85			
Tomato	Root	Bacteria	3	34.0	0.3472	7874				2090				110			
Tomato	Root	Bacteria	4	35.6	0.3292	8161				1963				101			
Tomato	Root	Fungus	1	50.8	0.2385	14299	16651	3775	0.23	4335	5407	880	0.16	259	265	33.09	0.12
Tomato	Root	Fungus	2	98.2	0.1145	20481				6321				249			
Tomato	Root	Fungus	3	42.2	0.284	12636				5082				313			
Tomato	Root	Fungus	4	96.8	0.1292	19187				5889				239			
Tomato	Root	Biosolid	1	26.6	0.3895	9672	7338	1947	0.27	4452	3734	550	0.15	175	146	23.13	0.16
Tomato	Root	Biosolid	2	23.6	0.4472	8211				3873				122			
Tomato	Root	Biosolid	3	19.9	0.5353	5825				3270				153			
Tomato	Root	Biosolid	4	20.2	0.5666	5643				3339				134			
Tomato	Root	Biosolid+Bacteria	1	48.3	0.264	9652	15368	5773	0.38	4894	7049	1866	0.26	142	192	46.06	0.24
Tomato	Root	Biosolid+Bacteria	2	43.4	0.2698	12473				6087				175			
Tomato	Root	Biosolid+Bacteria	3	70.4	0.154	16366				8690				199			
Tomato	Root	Biosolid+Bacteria	4	114.2	0.0891	22979				8526				251			
Tomato	Root	Biosolid+Fungus	1&2 Cp	108.9	0.1	26808	20039	6040	0.30	18257	17309	877	0.05	212	343	148.23	0.43
Tomato	Root	Biosolid+Fungus	3	74.7	0.1592	15202				17145				504			
Tomato	Root	Biosolid+Fungus	4	103.4	0.1037	18108				16525				314			
Tomato	Root	Compost	1	20.0	0.5944	22848	23502	6441	0.27	3180	3179	487	0.15	71	82	10.48	0.13
Tomato	Root	Compost	2	208.3	0.0542	32500				3863				75			
Tomato	Root	Compost	3	19.9	0.5836	21363				2904				93			
Tomato	Root	Compost	4	20.0	0.6509	17296				2769				87			
Tomato	Root	Compost+Bacteria	1	24.0	0.4445	24287	29564	4606	0.16	4879	8520	3185	0.37	149	157	93.10	0.59
Tomato	Root	Compost+Bacteria	2		0.4907												
Tomato	Root	Compost+Bacteria	3	38.8	0.3196	31627				9891				68			
Tomato	Root	Compost+Bacteria	4	26.0	0.442	32778				10789				254			
Tomato	Root	Compost+Fungus	1	24.3	0.4794	15244	15490	1326	0.09	2602	2649	161	0.06	85	77	8.30	0.11
Tomato	Root	Compost+Fungus	2	29.4	0.3708	16098				2489				68			
Tomato	Root	Compost+Fungus	3	32.7	0.3577	16856				2872				73			
Tomato	Root	Compost+Fungus	4	29.3	0.3833	13764				2634				82			

Table 48 Nutrient Concentrations in Tomato Roots Continued 2

Treatment	Rep.	Dilution Factor	(TR) Biomass	(TR) Ca	(TR) P	(TR) P Avg	(TR) P Stdv	(TR) P CV	(TR) S	(TR) S Avg	(TR) S Stdv	(TR) S CV	(TR) Zn	(TR) Zn Avg	(TR) Zn Stdv	(TR) Zn CV
Control	1	24.8	0.447	5443	1342.19	1292	124	0.10	2739	2904	326	0.11	233	212	38	0.18
Control	2	20.0	0.5866	5485	1242.36				2889				170			
Control	3	19.9	0.5885	5554	1435				3365				252			
Control	4	19.9	0.5535	4903	1148				2623				191			
Bacteria	1	31.3	0.368	2608	1797	2166	346	0.16	1504	1654	222	0.13	143	156	11	0.07
Bacteria	2	40.0	0.291	3359	2620				1984				158			
Bacteria	3	34.0	0.3472	2795	2207				1574				168			
Bacteria	4	35.6	0.3292	2630	2042				1554				154			
Fungus	1	50.8	0.2385	6265	3294	3589	476	0.13	3672	4215	410	0.10	228	251	20	0.08
Fungus	2	98.2	0.1145	7867	3504				4152				277			
Fungus	3	42.2	0.284	7554	3272				4415				244			
Fungus	4	96.8	0.1292	7037	4287				4622				253			
Biosolid	1	26.6	0.3895	14207	1617	1246	263	0.21	4290	3249	762	0.23	205	157	33	0.21
Biosolid	2	23.6	0.4472	12770	1245				3347				146			
Biosolid	3	19.9	0.5353	12630	1052				2696				137			
Biosolid	4	20.2	0.5666	10196	1069				2662				138			
Biosolid+Bacteria	1	48.3	0.264	13300	1272	1820	455	0.25	2554	3699	856	0.23	157	202	31	0.15
Biosolid+Bacteria	2	43.4	0.2698	14538	1710				3577				218			
Biosolid+Bacteria	3	70.4	0.154	23585	1932				4522				207			
Biosolid+Bacteria	4	114.2	0.0891	23402	2365				4143				225			
Biosolid+Fungus	1&2 Cp	108.9	0.1	28780	6187	6390	186	0.03	10600	11399	978	0.09	334	461	112	0.24
Biosolid+Fungus	3	74.7	0.1592	26883	6552				12489				544			
Biosolid+Fungus	4	103.4	0.1037	21396	6431				11107				504			
Compost	1	20.0	0.5944	7603	3217	2770	777	0.28	2994	2176	838	0.39	108	138	77	0.55
Compost	2	208.3	0.0542	10808	1643				1008				253			
Compost	3	19.9	0.5836	6393	3346				2278				106			
Compost	4	20.0	0.6509	6221	2875				2424				86			
Compost+Bacteria	1	24.0	0.4445	8266	2860	3412	500	0.15	3095	4323	1088	0.25	106	125	21	0.17
Compost+Bacteria	2		0.4907													
Compost+Bacteria	3	38.8	0.3196	10388	3542				4709				149			
Compost+Bacteria	4	26.0	0.442	10690	3835				5165				121			
Compost+Fungus	1	24.3	0.4794	4308	2218	2207	113	0.05	1540	1569	180	0.11	95	90	9	0.10
Compost+Fungus	2	29.4	0.3708	3685	2221				1394				86			
Compost+Fungus	3	32.7	0.3577	4114	2333				1820				98			
Compost+Fungus	4	29.3	0.3833	3831	2057				1520				80			

Table 49 Nutrient Concentrations in Tomato Stems

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(TS) Biomass	(TS) Ca	(TS) Ca Avg	(TS) Ca Stdv	(TS) Ca CV	(TS) Cu	(TS) Cu Avg	(TS) Cu Stdv	(TS) Cu CV	(TS) Fe	(TS) Fe Avg	(TS) Fe Stdv	(TS) Fe CV
Tomato	Stem	Control	1	20.0	2.6171	15183	13712	2105	0.15	8.45	9.9	1.3	0.13	42.0	74.6	44.6	0.60
Tomato	Stem	Control	2	19.9	2.6197	10620				11.10				69.2			
Tomato	Stem	Control	3	19.9	3.1394	14171				9.35				139.2			
Tomato	Stem	Control	4	19.9	3.092	14877				10.85				47.9			
Tomato	Stem	Bacteria	1	20.0	1.6553	17485	20465	3123	0.15	24.73	12.4	8.2	0.67	76.2	109.0	29.1	0.27
Tomato	Stem	Bacteria	2	19.9	1.4834	24612				8.04				128.1			
Tomato	Stem	Bacteria	3	20.0	1.5646	21000				8.87				93.4			
Tomato	Stem	Bacteria	4	19.9	1.5249	18765				7.90				138.4			
Tomato	Stem	Fungus	1	30.7	1.0491	20504	19247	2236	0.12	6.84	10.0	5.6	0.56	145.5	124.0	51.3	0.41
Tomato	Stem	Fungus	2	48.9	0.7111	19481				3.84				183.4			
Tomato	Stem	Fungus	3	19.9	1.5365	16025				15.35				65.8			
Tomato	Stem	Fungus	4	24.9	1.0134	20976				14.09				101.5			
Tomato	Stem	Biosolid	1	19.9	3.1091	20722	22761	2230	0.10	11.36	11.1	0.7	0.06	165.7	94.3	48.8	0.52
Tomato	Stem	Biosolid	2	20.0	3.2484	25685				10.34				55.9			
Tomato	Stem	Biosolid	3	19.9	3.6717	21366				11.91				74.2			
Tomato	Stem	Biosolid	4	19.9	3.7789	23273				10.74				81.2			
Tomato	Stem	Biosolid+Bacteria	1	19.9	1.4156	23295	24752	1028	0.04	9.09	10.2	4.4	0.44	62.4	71.9	16.4	0.23
Tomato	Stem	Biosolid+Bacteria	2	20.0	1.4364	24781				8.17				55.0			
Tomato	Stem	Biosolid+Bacteria	3	27.2	0.9149	25581				6.71				78.3			
Tomato	Stem	Biosolid+Bacteria	4	35.6	0.8058	25350				16.65				91.7			
Tomato	Stem	Biosolid+Fungus	1	81.6	0.3808	34212	30953	3938	0.13	8.62	7.7	1.2	0.16	353.1	177.3	119.0	0.67
Tomato	Stem	Biosolid+Fungus	2	70.0	0.5428	29461				6.07				147.1			
Tomato	Stem	Biosolid+Fungus	3	38.0	0.7173	34076				7.43				109.8			
Tomato	Stem	Biosolid+Fungus	4	41.7	0.7209	26062				8.54				99.4			
Tomato	Stem	Compost	1	19.9	3.0636	8854	12874	7100	0.55	4.20	5.2	2.9	0.55	34.9	60.9	51.8	0.85
Tomato	Stem	Compost	2	25.0	0.9465	23491				9.51				138.6			
Tomato	Stem	Compost	3	20.0	3.0351	10126				3.76				36.8			
Tomato	Stem	Compost	4	19.9	2.7042	9026				3.47				33.2			
Tomato	Stem	Compost+Bacteria	1	20.0	1.9559	15433	13766	1206	0.09	5.86	5.5	0.3	0.05	75.2	77.9	25.8	0.33
Tomato	Stem	Compost+Bacteria	2	19.9	1.8734	13763				5.39				56.0			
Tomato	Stem	Compost+Bacteria	3	20.0	1.8198	12621				5.35				114.9			
Tomato	Stem	Compost+Bacteria	4	19.9	2.1364	13246				5.26				65.7			
Tomato	Stem	Compost+Fungus	1	20.0	2.2802	12028	13618	1322	0.10	4.89	5.1	0.7	0.14	42.2	58.9	12.5	0.21
Tomato	Stem	Compost+Fungus	2	20.0	1.8096	13352				4.94				56.8			
Tomato	Stem	Compost+Fungus	3	19.9	2.1381	15225				6.14				66.7			
Tomato	Stem	Compost+Fungus	4	20.0	1.9009	13866				4.51				69.9			

Table 50 Nutrient Concentrations in Tomato Stems Continued 1

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(TS) Biomass	(TS) K	(TS) K Avg	(TS) K Stdv	(TS) K CV	(TS) Mg	(TS) Mg Avg	(TS) Mg Stdv	(TS) Mg CV	(TS) Mn	(TS) Mn Avg	(TS) Mn Stdev	(TS) Mn CV
Tomato	Stem	Control	1	20.0	2.6171	37178	27134	6889	0.25	5163	5136	243	0.05	141.5	120.1	16.3	0.14
Tomato	Stem	Control	2	19.9	2.6197	21906				4800				104.6			
Tomato	Stem	Control	3	19.9	3.1394	23588				5207				123.5			
Tomato	Stem	Control	4	19.9	3.092	25866				5376				110.7			
Tomato	Stem	Bacteria	1	20.0	1.6553	32501	34327	5439	0.16	5258	5751	445	0.08	73.5	83.0	12.5	0.15
Tomato	Stem	Bacteria	2	19.9	1.4834	34162				5939				99.5			
Tomato	Stem	Bacteria	3	20.0	1.5646	41780				6270				86.0			
Tomato	Stem	Bacteria	4	19.9	1.5249	28864				5538				72.9			
Tomato	Stem	Fungus	1	30.7	1.0491	37623	40028	4226	0.11	2482	2680	204	0.08	79.6	74.0	10.3	0.14
Tomato	Stem	Fungus	2	48.9	0.7111	41546				2752				58.5			
Tomato	Stem	Fungus	3	19.9	1.5365	35723				2553				79.4			
Tomato	Stem	Fungus	4	24.9	1.0134	45219				2933				78.5			
Tomato	Stem	Biosolid	1	19.9	3.1091	41344	40101	4456	0.11	4366	4409	186	0.04	54.2	55.3	5.5	0.10
Tomato	Stem	Biosolid	2	20.0	3.2484	45033				4659				61.3			
Tomato	Stem	Biosolid	3	19.9	3.6717	34309				4211				48.4			
Tomato	Stem	Biosolid	4	19.9	3.7789	39717				4400				57.2			
Tomato	Stem	Biosolid+Bacteria	1	19.9	1.4156	49900	51413	3668	0.07	2978	3177	214	0.07	38.2	45.6	6.2	0.14
Tomato	Stem	Biosolid+Bacteria	2	20.0	1.4364	47606				3011				47.2			
Tomato	Stem	Biosolid+Bacteria	3	27.2	0.9149	51901				3400				53.1			
Tomato	Stem	Biosolid+Bacteria	4	35.6	0.8058	56243				3319				43.9			
Tomato	Stem	Biosolid+Fungus	1	81.6	0.3808	66629	51364	11485	0.22	4919	3930	662	0.17	53.0	47.9	10.3	0.22
Tomato	Stem	Biosolid+Fungus	2	70.0	0.5428	39195				3650				38.0			
Tomato	Stem	Biosolid+Fungus	3	38.0	0.7173	52030				3631				59.9			
Tomato	Stem	Biosolid+Fungus	4	41.7	0.7209	47601				3519				40.7			
Tomato	Stem	Compost	1	19.9	3.0636	29545	38489	22230	0.58	1691	1995	668	0.33	52.9	39.2	11.3	0.29
Tomato	Stem	Compost	2	25.0	0.9465	71735				2996				40.2			
Tomato	Stem	Compost	3	20.0	3.0351	25350				1655				38.5			
Tomato	Stem	Compost	4	19.9	2.7042	27325				1637				25.3			
Tomato	Stem	Compost+Bacteria	1	20.0	1.9559	42469	40360	1464	0.04	1943	1799	96	0.05	40.7	38.1	6.4	0.17
Tomato	Stem	Compost+Bacteria	2	19.9	1.8734	39098				1756				29.1			
Tomato	Stem	Compost+Bacteria	3	20.0	1.8198	40048				1756				38.7			
Tomato	Stem	Compost+Bacteria	4	19.9	2.1364	39825				1741				43.8			
Tomato	Stem	Compost+Fungus	1	20.0	2.2802	42706	42653	5200	0.12	1865	1872	53	0.03	28.9	29.3	3.9	0.13
Tomato	Stem	Compost+Fungus	2	20.0	1.8096	42260				1832				27.6			
Tomato	Stem	Compost+Fungus	3	19.9	2.1381	49183				1948				34.8			
Tomato	Stem	Compost+Fungus	4	20.0	1.9009	36464				1841				26.0			

Table 51 Nutrient Concentrations in Tomato Stems Continued 2

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(TS) Biomass	(TS) P	(TS) P Avg	(TS) P Stdv	(TS) P CV	(TS) S	(TS) S Avg	(TS) S Stdv	(TS) S CV	(TS) Zn	(TS) Zn Avg	(TS) Zn Stdv	(TS) Zn CV
Tomato	Stem	Control	1	20.0	2.6171	4555	4365	962	0.22	2764	2839	690	0.24	234	254	32	0.12
Tomato	Stem	Control	2	19.9	2.6197	5617				3795				233			
Tomato	Stem	Control	3	19.9	3.1394	3387				2152				300			
Tomato	Stem	Control	4	19.9	3.092	3899				2646				249			
Tomato	Stem	Bacteria	1	20.0	1.6553	7936	6238	1253	0.20	6069	5042	1475	0.29	355	364	39	0.11
Tomato	Stem	Bacteria	2	19.9	1.4834	5553				4606				408			
Tomato	Stem	Bacteria	3	20.0	1.5646	6380				6346				315			
Tomato	Stem	Bacteria	4	19.9	1.5249	5081				3149				378			
Tomato	Stem	Fungus	1	30.7	1.0491	1921	2813	1446	0.51	2488	4199	2473	0.59	308	223	64	0.29
Tomato	Stem	Fungus	2	48.9	0.7111	1248				1842				154			
Tomato	Stem	Fungus	3	19.9	1.5365	3977				5342				226			
Tomato	Stem	Fungus	4	24.9	1.0134	4106				7124				203			
Tomato	Stem	Biosolid	1	19.9	3.1091	2836	2608	179	0.07	3656	4166	1102	0.26	121	116	14	0.12
Tomato	Stem	Biosolid	2	20.0	3.2484	2401				5501				104			
Tomato	Stem	Biosolid	3	19.9	3.6717	2581				2959				134			
Tomato	Stem	Biosolid	4	19.9	3.7789	2614				4547				105			
Tomato	Stem	Biosolid+Bacteria	1	19.9	1.4156	2320	2128	451	0.21	3173	3927	1377	0.35	139	125	21	0.16
Tomato	Stem	Biosolid+Bacteria	2	20.0	1.4364	1820				3007				135			
Tomato	Stem	Biosolid+Bacteria	3	27.2	0.9149	1701				3566				95			
Tomato	Stem	Biosolid+Bacteria	4	35.6	0.8058	2673				5962				133			
Tomato	Stem	Biosolid+Fungus	1	81.6	0.3808	1329	1372	57	0.04	1981	1700	287	0.17	168	181	18	0.10
Tomato	Stem	Biosolid+Fungus	2	70.0	0.5428	1324				1317				185			
Tomato	Stem	Biosolid+Fungus	3	38.0	0.7173	1443				1839				205			
Tomato	Stem	Biosolid+Fungus	4	41.7	0.7209	1395				1662				166			
Tomato	Stem	Compost	1	19.9	3.0636	2380	3047	941	0.31	1227	1913	1235	0.65	119	128	44	0.34
Tomato	Stem	Compost	2	25.0	0.9465	4417				3758				192			
Tomato	Stem	Compost	3	20.0	3.0351	2487				1461				108			
Tomato	Stem	Compost	4	19.9	2.7042	2902				1206				93			
Tomato	Stem	Compost+Bacteria	1	20.0	1.9559	3366	3017	274	0.09	2467	1990	350	0.18	131	129	10	0.08
Tomato	Stem	Compost+Bacteria	2	19.9	1.8734	3013				1736				141			
Tomato	Stem	Compost+Bacteria	3	20.0	1.8198	2697				1720				124			
Tomato	Stem	Compost+Bacteria	4	19.9	2.1364	2993				2039				119			
Tomato	Stem	Compost+Fungus	1	20.0	2.2802	3351	3171	406	0.13	2002	2069	370	0.18	130	135	10	0.07
Tomato	Stem	Compost+Fungus	2	20.0	1.8096	3286				2102				124			
Tomato	Stem	Compost+Fungus	3	19.9	2.1381	3475				2535				142			
Tomato	Stem	Compost+Fungus	4	20.0	1.9009	2573				1636				145			

Table 52 Nutrient Concentrations in Tomato Leaves

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(TL) Biomass	(TL) Ca	(TL) Ca Avg	(TL) Ca Stdv	(TL) Ca CV	(TL) Cu	(TL) Cu Avg	(TL) Cu Stdv	(TL) Cu CV	(TL) Fe	(TL) Fe Avg	(TL) Fe Stdv	(TL) Fe CV
Tomato	Leaves	Control	1	20.0	2.6171	31610	34049	1840	0.05	13.6	13.7	2.9	0.21	140	215	113	0.52
Tomato	Leaves	Control	2	20.0	2.6197	36017				9.9				183			
Tomato	Leaves	Control	3	19.9	3.1394	34618				16.8				382			
Tomato	Leaves	Control	4	19.9	3.092	33950				14.6				156			
Tomato	Leaves	Bacteria	1	19.9	1.6553	28090	24774	2478	0.10	14.0	14.0	1.1	0.08	232	236	83	0.35
Tomato	Leaves	Bacteria	2	20.0	1.4834	25205				14.6				206			
Tomato	Leaves	Bacteria	3	19.9	1.5646	23244				15.0				154			
Tomato	Leaves	Bacteria	4	20.0	1.5249	22559				12.5				351			
Tomato	Leaves	Fungus	1	20.0	1.0491	31234	31298	1596	0.05	23.3	18.1	4.6	0.25	478	327	144	0.44
Tomato	Leaves	Fungus	2	21.7	0.7111	29111				12.6				422			
Tomato	Leaves	Fungus	3	19.9	1.5365	32028				19.7				198			
Tomato	Leaves	Fungus	4	20.0	1.0134	32821				16.8				210			
Tomato	Leaves	Biosolid	1	19.9	3.1091	19089	24425	3880	0.16	13.8	15.8	1.5	0.09	391	215	119	0.55
Tomato	Leaves	Biosolid	2	19.9	3.2484	28194				17.3				151			
Tomato	Leaves	Biosolid	3	20.0	3.6717	25998				16.1				182			
Tomato	Leaves	Biosolid	4	20.0	3.7789	24421				16.2				135			
Tomato	Leaves	Biosolid+Bacteria	1	20.0	1.4156	35016	37219	9388	0.25	22.3	16.9	9.1	0.54	215	197	53	0.27
Tomato	Leaves	Biosolid+Bacteria	2	20.0	1.4364	31484				19.0				123			
Tomato	Leaves	Biosolid+Bacteria	3	20.7	0.9149	51066				22.8				250			
Tomato	Leaves	Biosolid+Bacteria	4	21.4	0.8058	31310				3.5				199			
Tomato	Leaves	Biosolid+Fungus	1	46.8	0.3808	58661	55878	2218	0.04	25.6	27.2	4.8	0.18	857	418	298	0.71
Tomato	Leaves	Biosolid+Fungus	2	26.6	0.5428	53486				34.0				350			
Tomato	Leaves	Biosolid+Fungus	3	22.5	0.7173	54903				22.8				224			
Tomato	Leaves	Biosolid+Fungus	4	22.3	0.7209	56463				26.5				240			
Tomato	Leaves	Compost	1	19.9	3.0636	34129	37597	4489	0.12	7.2	11.4	4.7	0.42	129	144	20	0.14
Tomato	Leaves	Compost	2	20.0	0.9465	44158				18.2				155			
Tomato	Leaves	Compost	3	20.0	3.0351	35503				10.0				166			
Tomato	Leaves	Compost	4	19.9	2.7042	36596				10.2				124			
Tomato	Leaves	Compost+Bacteria	1	20.0	1.9559	36464	34393	5254	0.15	18.3	18.2	2.4	0.13	271	313	97	0.31
Tomato	Leaves	Compost+Bacteria	2	19.9	1.8734	40873				21.5				381			
Tomato	Leaves	Compost+Bacteria	3	20.0	1.8198	30138				15.9				403			
Tomato	Leaves	Compost+Bacteria	4	19.9	2.1364	30099				17.0				197			
Tomato	Leaves	Compost+Fungus	1	20.0	2.2802	35415	36709	1158	0.03	17.5	21.5	4.8	0.22	269	292	26	0.09
Tomato	Leaves	Compost+Fungus	2	20.0	1.8096	36839				18.7				270			
Tomato	Leaves	Compost+Fungus	3	19.9	2.1381	38200				21.5				322			
Tomato	Leaves	Compost+Fungus	4	19.9	1.9009	36382				28.2				305			

Table 53 Nutrient Concentrations in Tomato Leaves Continued 1

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(TL) Biomass	(TL) K	(TL) K Avg	(TL) K Stdv	(TL) K CV	(TL) Mg	(TL) Mg Avg	(TL) Mg Stdv	(TL) Mg CV	(TL) Mn	(TL) Mn Avg	(TL) Mn Stdv	(TL) Mn CV
Tomato	Leaves	Control	1	20.0	2.6171	36240.27	39969	4738	0.12	3818	3819	19	0.01	379	375	42	0.11
Tomato	Leaves	Control	2	20.0	2.6197	35876.95				3805				424			
Tomato	Leaves	Control	3	19.9	3.1394	45627.98				3806				375			
Tomato	Leaves	Control	4	19.9	3.092	42129.35				3847				322			
Tomato	Leaves	Bacteria	1	19.9	1.6553	41586.92	37989	3221	0.08	2801	2658	117	0.04	172	143	24	0.17
Tomato	Leaves	Bacteria	2	20.0	1.4834	39564.61				2706				152			
Tomato	Leaves	Bacteria	3	19.9	1.5646	34328.36				2563				118			
Tomato	Leaves	Bacteria	4	20.0	1.5249	36474.35				2561				131			
Tomato	Leaves	Fungus	1	20.0	1.0491	47790.44	46270	6428	0.14	6483	6728	308	0.05	221	209	47	0.23
Tomato	Leaves	Fungus	2	21.7	0.7111	53899.63				6987				152			
Tomato	Leaves	Fungus	3	19.9	1.5365	38409.54				6439				265			
Tomato	Leaves	Fungus	4	20.0	1.0134	44979.04				7001				198			
Tomato	Leaves	Biosolid	1	19.9	3.1091	23290.13	29095	5636	0.19	2317	2707	263	0.10	60	70	8	0.11
Tomato	Leaves	Biosolid	2	19.9	3.2484	27975.36				2887				72			
Tomato	Leaves	Biosolid	3	20.0	3.6717	36821.09				2825				78			
Tomato	Leaves	Biosolid	4	20.0	3.7789	28294.73				2800				69			
Tomato	Leaves	Biosolid+Bacteria	1	20.0	1.4156	40881.88	43593	5580	0.13	2851	3206	758	0.24	85	99	30	0.30
Tomato	Leaves	Biosolid+Bacteria	2	20.0	1.4364	37470.07				2809				85			
Tomato	Leaves	Biosolid+Bacteria	3	20.7	0.9149	50196.65				4343				143			
Tomato	Leaves	Biosolid+Bacteria	4	21.4	0.8058	45821.76				2821				83			
Tomato	Leaves	Biosolid+Fungus	1	46.8	0.3808	53277.15	51811	4448	0.09	9045	7892	1211	0.15	179	158	18	0.11
Tomato	Leaves	Biosolid+Fungus	2	26.6	0.5428	56333.16				8324				141			
Tomato	Leaves	Biosolid+Fungus	3	22.5	0.7173	45748.99				6197				167			
Tomato	Leaves	Biosolid+Fungus	4	22.3	0.7209	51886.58				8004				146			
Tomato	Leaves	Compost	1	19.9	3.0636	52218.91	50975	13080	0.26	6669	6250	292	0.05	267	202	52	0.26
Tomato	Leaves	Compost	2	20.0	0.9465	68504.09				6014				209			
Tomato	Leaves	Compost	3	20.0	3.0351	45347.44				6224				194			
Tomato	Leaves	Compost	4	19.9	2.7042	37831.37				6095				140			
Tomato	Leaves	Compost+Bacteria	1	20.0	1.9559	62257.74	60752	6305	0.10	6470	6168	677	0.11	172	159	11	0.07
Tomato	Leaves	Compost+Bacteria	2	19.9	1.8734	68652.85				6961				159			
Tomato	Leaves	Compost+Bacteria	3	20.0	1.8198	58318.35				5790				144			
Tomato	Leaves	Compost+Bacteria	4	19.9	2.1364	53777.34				5453				160			
Tomato	Leaves	Compost+Fungus	1	20.0	2.2802	57142.86	61203	3998	0.07	5956	6243	208	0.03	139	139	9	0.06
Tomato	Leaves	Compost+Fungus	2	20.0	1.8096	59289.56				6254				137			
Tomato	Leaves	Compost+Fungus	3	19.9	2.1381	61958.68				6313				150			
Tomato	Leaves	Compost+Fungus	4	19.9	1.9009	66421.47				6447				129			

Table 54 Nutrient Concentrations in Tomato Leaves Continued 2

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(TL) Biomass	(TL) P	(TL) P Avg	(TL) P Stdv	(TL) P CV	(TL) S	(TL) S Avg	(TL) S Stdv	(TL) S CV	(TL) Zn	(TL) Zn Avg	(TL) Zn Stdv	(TL) Zn CV
Tomato	Leaves	Control	1	20.0	2.6171	4985	4480	725	0.16	11912	11572	1902	0.16	91.2	89.4	12.2	0.14
Tomato	Leaves	Control	2	20.0	2.6197	3438				8827				105.9			
Tomato	Leaves	Control	3	19.9	3.1394	4960				13170				79.0			
Tomato	Leaves	Control	4	19.9	3.092	4535				12380				81.5			
Tomato	Leaves	Bacteria	1	19.9	1.6553	3816	3561	197	0.06	9882	8932	798	0.09	126.3	127.6	10.2	0.08
Tomato	Leaves	Bacteria	2	20.0	1.4834	3579				8924				141.6			
Tomato	Leaves	Bacteria	3	19.9	1.5646	3508				8993				125.3			
Tomato	Leaves	Bacteria	4	20.0	1.5249	3342				7930				117.1			
Tomato	Leaves	Fungus	1	20.0	1.0491	10912	10135	1236	0.12	28914	27766	3698	0.13	222.4	165.9	40.6	0.24
Tomato	Leaves	Fungus	2	21.7	0.7111	8573				22789				127.0			
Tomato	Leaves	Fungus	3	19.9	1.5365	11312				31630				163.3			
Tomato	Leaves	Fungus	4	20.0	1.0134	9742				27730				150.9			
Tomato	Leaves	Biosolid	1	19.9	3.1091	2674	2910	242	0.08	6903	8001	771	0.10	52.4	60.3	9.4	0.16
Tomato	Leaves	Biosolid	2	19.9	3.2484	2929				8176				70.6			
Tomato	Leaves	Biosolid	3	20.0	3.6717	3239				8710				52.4			
Tomato	Leaves	Biosolid	4	20.0	3.7789	2800				8215				66.0			
Tomato	Leaves	Biosolid+Bacteria	1	20.0	1.4156	3901	2564	1393	0.54	10361	7956	4094	0.51	105.6	93.9	9.1	0.10
Tomato	Leaves	Biosolid+Bacteria	2	20.0	1.4364	3342				9240				93.9			
Tomato	Leaves	Biosolid+Bacteria	3	20.7	0.9149	2281				10358				92.4			
Tomato	Leaves	Biosolid+Bacteria	4	21.4	0.8058	733				1866				83.5			
Tomato	Leaves	Biosolid+Fungus	1	46.8	0.3808	7472	7719	460	0.06	35613	30362	3814	0.13	89.9	120.5	21.5	0.18
Tomato	Leaves	Biosolid+Fungus	2	26.6	0.5428	7584				27089				130.5			
Tomato	Leaves	Biosolid+Fungus	3	22.5	0.7173	7418				28070				122.5			
Tomato	Leaves	Biosolid+Fungus	4	22.3	0.7209	8401				30676				139.2			
Tomato	Leaves	Compost	1	19.9	3.0636	6846	7579	909	0.12	16302	17486	1894	0.11	133.6	114.8	27.3	0.24
Tomato	Leaves	Compost	2	20.0	0.9465	6826				19459				138.7			
Tomato	Leaves	Compost	3	20.0	3.0351	7955				15485				107.8			
Tomato	Leaves	Compost	4	19.9	2.7042	8688				18696				79.3			
Tomato	Leaves	Compost+Bacteria	1	20.0	1.9559	9267	8390	998	0.12	20679	20098	2978	0.15	163.6	156.9	18.3	0.12
Tomato	Leaves	Compost+Bacteria	2	19.9	1.8734	9239				24073				176.2			
Tomato	Leaves	Compost+Bacteria	3	20.0	1.8198	7448				17619				132.8			
Tomato	Leaves	Compost+Bacteria	4	19.9	2.1364	7608				18020				154.8			
Tomato	Leaves	Compost+Fungus	1	20.0	2.2802	9308	9569	1117	0.12	20072	22927	3588	0.16	164.3	143.3	36.9	0.26
Tomato	Leaves	Compost+Fungus	2	20.0	1.8096	10914				21493				121.2			
Tomato	Leaves	Compost+Fungus	3	19.9	2.1381	9827				21971				183.6			
Tomato	Leaves	Compost+Fungus	4	19.9	1.9009	8227				28171				104.1			

Table 55 Nutrient Concentrations in Radish Roots

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(RR) Biomass	(RR) Ca	(RR) Ca Avg	(RR) Ca Stdv	(RR) Ca CV	(RR) Cu	(RR) Cu Avg	(RR) Cu Stdv	(RR) Cu CV	(RR) Fe	(RR) Fe Avg	(RR) Fe Stdv	(RR) Fe CV
Radish	Root	Control	1	19.94	0.6505	13710	10672	2554	0.24	10.96	8.66	2.02	0.23	213	209	81	0.39
Radish	Root	Control	2	19.90	0.8749	10105				8.31				320			
Radish	Root	Control	3	19.92	1.2016	7570				6.12				172			
Radish	Root	Control	4	19.94	1.0188	11304				9.27				132			
Radish	Root	Bacteria	1	19.98	0.6882	5133	4988	921	0.18	0.25	4.86	2.49	0.51	88	108.6	16.5	0.15
Radish	Root	Bacteria	2	19.93	0.8413	6182				4.44				128			
Radish	Root	Bacteria	3	19.94	0.8967	4636				6.18				111			
Radish	Root	Bacteria	4	19.92	0.8167	4001				3.95				106			
Radish	Root	Fungus	1	27.25	0.3890	3995	4600	827	0.18	15.01	9.84	4.05	0.41	537	425.0	143.7	0.34
Radish	Root	Fungus	2	19.89	0.5579	3782				10.30				230			
Radish	Root	Fungus	3	37.11	0.2961	5321				5.26				403			
Radish	Root	Fungus	4	21.21	0.4987	5304				8.77				530			
Radish	Root	Biosolid	1	19.94	0.8668	10287	12714	1650	0.13	9.47	12.40	4.58	0.37	213	713.7	455.2	0.64
Radish	Root	Biosolid	2	19.93	0.6902	13685				8.73				471			
Radish	Root	Biosolid	3	20.35	0.5129	13067				12.59				953			
Radish	Root	Biosolid	4	30.35	0.3495	13815				18.80				1219			
Radish	Root	Biosolid+Bacteria	1	19.95	1.7968	8657	8157	1433	0.18	5.63	6.03	0.93	0.15	119	280.1	285.6	1.02
Radish	Root	Biosolid+Bacteria	2	19.90	1.9157	8338				5.63				83			
Radish	Root	Biosolid+Bacteria	3	19.92	1.2033	9496				7.42				700			
Radish	Root	Biosolid+Bacteria	4	19.96	2.0001	6136				5.43				219			
Radish	Root	Biosolid+Fungus	1	19.94	1.1582	6013	8718	3433	0.39	5.36	5.07	1.19	0.24	223	138.6	72.1	0.52
Radish	Root	Biosolid+Fungus	2	19.86	0.8006	12906				5.40				174			
Radish	Root	Biosolid+Fungus	3	19.91	0.7429	5808				3.37				68			
Radish	Root	Biosolid+Fungus	4	19.92	0.8654	10145				6.16				90			
Radish	Root	Compost	1	19.90	0.7466	6342	7272	1610	0.22	5.92	4.86	0.77	0.16	89	78.1	19.1	0.24
Radish	Root	Compost	2	19.89	0.9356	8528				4.89				94			
Radish	Root	Compost	3	19.90	0.7731	5483				4.13				52			
Radish	Root	Compost	4	19.94	1.1096	8734				4.52				77			
Radish	Root	Compost+Bacteria	1	19.98	0.9880	4778	8268	2885	0.35	0.89	2.53	2.51	0.99	44	105.4	78.6	0.75
Radish	Root	Compost+Bacteria	2	19.92	0.6294	11054				1.28				63			
Radish	Root	Compost+Bacteria	3	19.94	0.6148	7074				1.70				95			
Radish	Root	Compost+Bacteria	4	19.97	0.5038	10166				6.26				219			
Radish	Root	Compost+Fungus	1	19.98	0.9815	8615	9556	2355	0.25	3.53	3.98	2.03	0.51	149	137.9	78.6	0.57
Radish	Root	Compost+Fungus	2	19.95	0.9112	6710				1.55				59			
Radish	Root	Compost+Fungus	3	19.90	0.5429	10955				4.39				102			
Radish	Root	Compost+Fungus	4	19.91	0.6151	11943				6.45				242			

Table 56 Nutrient Concentrations in Radish Roots Continued 1

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(RR) Biomass	(RR) K	(RR) K Avg	(RR) K Stdv	(RR) K CV	(RR) Mg	(RR) Mg Avg	(RR) Mg Stdv	(RR) Mg CV	(RR) Mn	(RR) Mn Avg	(RR) Mn Stdv	(RR) Mn CV
Radish	Root	Control	1	19.94	0.6505	45612	46510	7118	0.15	5425	4726	1188	0.25	44.5	37.79	9.01	0.24
Radish	Root	Control	2	19.90	0.8749	37067				3311				46.3			
Radish	Root	Control	3	19.92	1.2016	49612				4222				27.9			
Radish	Root	Control	4	19.94	1.0188	53750				5947				32.4			
Radish	Root	Bacteria	1	19.98	0.6882	36124	32062	4858	0.15	1436	1378	127	0.09	14.4	16.19	2.06	0.13
Radish	Root	Bacteria	2	19.93	0.8413	30490				1275				18.5			
Radish	Root	Bacteria	3	19.94	0.8967	35753				1530				17.4			
Radish	Root	Bacteria	4	19.92	0.8167	25882				1272				14.5			
Radish	Root	Fungus	1	27.25	0.3890	32452	41013	7878	0.19	2393	2024	264	0.13	34.4	40.10	10.64	0.27
Radish	Root	Fungus	2	19.89	0.5579	36204				1769				32.1			
Radish	Root	Fungus	3	37.11	0.2961	48163				1939				55.6			
Radish	Root	Fungus	4	21.21	0.4987	47232				1997				38.4			
Radish	Root	Biosolid	1	19.94	0.8668	54975	45248	12703	0.28	2243	2030	393	0.19	19.0	34.14	12.01	0.35
Radish	Root	Biosolid	2	19.93	0.6902	52551				2304				30.1			
Radish	Root	Biosolid	3	20.35	0.5129	46509				2121				45.4			
Radish	Root	Biosolid	4	30.35	0.3495	26956				1451				42.0			
Radish	Root	Biosolid+Bacteria	1	19.95	1.7968	39118	37960	1794	0.05	3034	2944	208	0.07	13.8	18.37	6.81	0.37
Radish	Root	Biosolid+Bacteria	2	19.90	1.9157	39463				2820				18.9			
Radish	Root	Biosolid+Bacteria	3	19.92	1.2033	37749				3191				27.8			
Radish	Root	Biosolid+Bacteria	4	19.96	2.0001	35509				2733				13.0			
Radish	Root	Biosolid+Fungus	1	19.94	1.1582	37036	41166	4905	0.12	1226	1632	457	0.28	19.0	17.08	6.51	0.38
Radish	Root	Biosolid+Fungus	2	19.86	0.8006	42781				2195				25.3			
Radish	Root	Biosolid+Fungus	3	19.91	0.7429	37455				1296				10.5			
Radish	Root	Biosolid+Fungus	4	19.92	0.8654	47390				1811				13.5			
Radish	Root	Compost	1	19.90	0.7466	51075	46621	7982	0.17	2402	2158	379	0.18	17.5	15.80	5.75	0.36
Radish	Root	Compost	2	19.89	0.9356	53352				2506				23.1			
Radish	Root	Compost	3	19.90	0.7731	35396				1670				10.4			
Radish	Root	Compost	4	19.94	1.1096	46660				2052				12.1			
Radish	Root	Compost+Bacteria	1	19.98	0.9880	37770	45972	7192	0.16	1535	1879	280	0.15	7.7	14.13	4.64	0.33
Radish	Root	Compost+Bacteria	2	19.92	0.6294	53118				2098				14.3			
Radish	Root	Compost+Bacteria	3	19.94	0.6148	50758				1768				15.9			
Radish	Root	Compost+Bacteria	4	19.97	0.5038	42241				2117				18.7			
Radish	Root	Compost+Fungus	1	19.98	0.9815	39908	43832	3279	0.07	3843	4030	509	0.13	13.1	12.87	1.44	0.11
Radish	Root	Compost+Fungus	2	19.95	0.9112	42538				3400				11.2			
Radish	Root	Compost+Fungus	3	19.90	0.5429	47323				4515				12.4			
Radish	Root	Compost+Fungus	4	19.91	0.6151	45560				4361				14.7			

Table 57 Nutrient Concentrations in Radish Roots Continued 2

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(RR) Biomass	(RR) P	(RR) P Avg	(RR) P Stdv	(RR) P CV	(RR) S	(RR) S Avg	(RR) S Stdv	(RR) S CV	(RR) Zn	(RR) Zn Avg	(RR) Zn Stdv	(RR) Zn CV
Radish	Root	Control	1	19.94	0.6505	12956	13707	766	0.06	14832	16460	2409	0.15	230	173	58	0.33
Radish	Root	Control	2	19.90	0.8749	13162				15430				99			
Radish	Root	Control	3	19.92	1.2016	14190				15535				156			
Radish	Root	Control	4	19.94	1.0188	14521				20044				204			
Radish	Root	Bacteria	1	19.98	0.6882	271	3890	1836	0.47	330	4123	2099	0.51	88	102	11	0.11
Radish	Root	Bacteria	2	19.93	0.8413	3543				3023				114			
Radish	Root	Bacteria	3	19.94	0.8967	4299				4118				109			
Radish	Root	Bacteria	4	19.92	0.8167	3827				5228				98			
Radish	Root	Fungus	1	27.25	0.3890	6079	6943	2195	0.32	9455	6468	3414	0.53	104	140	33	0.23
Radish	Root	Fungus	2	19.89	0.5579	10209				9278				166			
Radish	Root	Fungus	3	37.11	0.2961	5466				2748				170			
Radish	Root	Fungus	4	21.21	0.4987	6019				4390				122			
Radish	Root	Biosolid	1	19.94	0.8668	2861	3207	462	0.14	6945	6028	1012	0.17	45	50	6	0.12
Radish	Root	Biosolid	2	19.93	0.6902	3151				6794				45			
Radish	Root	Biosolid	3	20.35	0.5129	3875				5526				57			
Radish	Root	Biosolid	4	30.35	0.3495	2941				4847				53			
Radish	Root	Biosolid+Bacteria	1	19.95	1.7968	9029	8536	402	0.05	7381	7253	105	0.01	43	69	28	0.40
Radish	Root	Biosolid+Bacteria	2	19.90	1.9157	8171				7232				72			
Radish	Root	Biosolid+Bacteria	3	19.92	1.2033	8249				7271				106			
Radish	Root	Biosolid+Bacteria	4	19.96	2.0001	8697				7128				56			
Radish	Root	Biosolid+Fungus	1	19.94	1.1582	3235	2887	322	0.11	4196	4078	710	0.17	55	60	9	0.15
Radish	Root	Biosolid+Fungus	2	19.86	0.8006	2554				4713				74			
Radish	Root	Biosolid+Fungus	3	19.91	0.7429	2682				3065				58			
Radish	Root	Biosolid+Fungus	4	19.92	0.8654	3078				4337				54			
Radish	Root	Compost	1	19.90	0.7466	6712	6722	968	0.14	7536	6046	1252	0.21	57	46	9	0.20
Radish	Root	Compost	2	19.89	0.9356	7126				5433				50			
Radish	Root	Compost	3	19.90	0.7731	5392				4680				36			
Radish	Root	Compost	4	19.94	1.1096	7659				6534				41			
Radish	Root	Compost+Bacteria	1	19.98	0.9880	1530	2313	1086	0.47	1837	2372	999	0.42	33	60	23	0.38
Radish	Root	Compost+Bacteria	2	19.92	0.6294	2212				2038				61			
Radish	Root	Compost+Bacteria	3	19.94	0.6148	1631				1754				59			
Radish	Root	Compost+Bacteria	4	19.97	0.5038	3879				3861				88			
Radish	Root	Compost+Fungus	1	19.98	0.9815	8169	8164	2345	0.29	6601	7632	2965	0.39	58	74	17	0.23
Radish	Root	Compost+Fungus	2	19.95	0.9112	4910				3935				69			
Radish	Root	Compost+Fungus	3	19.90	0.5429	10352				9520				98			
Radish	Root	Compost+Fungus	4	19.91	0.6151	9225				10474				72			

Table 58 Nutrient Concentrations in Radish Shoots

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(RS) Biomass	(RS) Ca	(RS) Ca Avg	(RS) Ca Stdv	(RS) Ca CV	(RS) Cu	(RS) Cu Avg	(RS) Cu Stdv	(RS) Cu CV	(RS) Fe	(RS) Fe Avg	(RS) Fe Stdv	(RS) Fe CV
Radish	Shoot	Control	1	20.0	1.0405	39884	39349	1245	0.03	11.6	8	3	0.39	176	147	20	0.14
Radish	Shoot	Control	2	19.9	1.1025	40521				8.4				132			
Radish	Shoot	Control	3	19.9	0.9265	37620				3.9				141			
Radish	Shoot	Control	4	19.9	1.1874	39371				8.5				138			
Radish	Shoot	Bacteria	1	19.9	0.6932	36398	36031	4218	0.12	8.9	8	1	0.08	329	251	63	0.25
Radish	Shoot	Bacteria	2	20.0	1.0097	37612				8.8				276			
Radish	Shoot	Bacteria	3	19.9	1.0604	30115				8.1				203			
Radish	Shoot	Bacteria	4	20.0	0.9852	40000				7.5				196			
Radish	Shoot	Fungus	1	19.9	1.0051	37827	36308	1944	0.05	9.3	11	3	0.24	900	581	249	0.43
Radish	Shoot	Fungus	2	19.9	1.1958	33466				8.8				292			
Radish	Shoot	Fungus	3	19.9	1.0067	36766				14.6				566			
Radish	Shoot	Fungus	4	19.9	1.1057	37174				11.0				565			
Radish	Shoot	Biosolid	1	19.9	1.666	36908	31721	5286	0.17	7.6	9	1	0.13	140	184	54	0.30
Radish	Shoot	Biosolid	2	19.9	1.3155	35506				10.3				238			
Radish	Shoot	Biosolid	3	19.9	1.3482	26150				8.6				134			
Radish	Shoot	Biosolid	4	19.9	1.3712	28321				9.7				222			
Radish	Shoot	Biosolid+Bacteria	1	20.0	1.561	42851	42425	3026	0.07	0.9	5	3	0.61	239	207	44	0.21
Radish	Shoot	Biosolid+Bacteria	2	19.9	1.5061	46401				4.8				206			
Radish	Shoot	Biosolid+Bacteria	3	20.0	1.7076	39280				7.9				238			
Radish	Shoot	Biosolid+Bacteria	4	19.9	1.6876	41166				6.7				145			
Radish	Shoot	Biosolid+Fungus	1	19.9	1.4681	46008	43209	2823	0.07	8.9	8	0	0.05	205	322	93	0.29
Radish	Shoot	Biosolid+Fungus	2	19.9	1.2297	39956				8.5				318			
Radish	Shoot	Biosolid+Fungus	3	20.0	1.1227	41795				7.8				332			
Radish	Shoot	Biosolid+Fungus	4	19.9	0.9917	45076				8.4				433			
Radish	Shoot	Compost	1	19.9	0.7248	42806	50743	10901	0.21	5.9	6	0	0.07	271	249	33	0.13
Radish	Shoot	Compost	2	19.9	0.6952	47213				5.2				236			
Radish	Shoot	Compost	3	19.9	0.7974	46102				6.1				210			
Radish	Shoot	Compost	4	19.9	0.6325	66852				5.9				281			
Radish	Shoot	Compost+Bacteria	1	20.0	0.8459	36213	37777	2761	0.07	4.9	6	1	0.19	328	289	36	0.12
Radish	Shoot	Compost+Bacteria	2	19.9	0.8892	39697				6.3				241			
Radish	Shoot	Compost+Bacteria	3	19.9	0.7806	40486				8.0				290			
Radish	Shoot	Compost+Bacteria	4	19.9	0.7576	34712				6.6				295			
Radish	Shoot	Compost+Fungus	1	19.9	0.7179	51343	43578	9064	0.21	6.0	6	1	0.12	335	297	46	0.15
Radish	Shoot	Compost+Fungus	2	19.9	0.6589	43785				4.7				248			
Radish	Shoot	Compost+Fungus	3	19.9	0.6047	48377				6.4				338			
Radish	Shoot	Compost+Fungus	4	20.0	0.8755	30808				5.6				269			

Table 59 Nutrient Concentrations in Radish Shoots Continued 1

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(RS) Biomass	(RS) K	(RS) K Avg	(RS) K Stdv	(RS) K CV	(RS) Mg	(RS) Mg Avg	(RS) Mg Stdv	(RS) Mg CV	(RS) Mn	(RS) Mn Avg	(RS) Mn Stdv	(RS) Mn CV
Radish	Shoot	Control	1	20.0	1.0405	28332	27657	5684	0.21	3542	3396	360	0.11	192	163	36	0.22
Radish	Shoot	Control	2	19.9	1.1025	34394				3760				112			
Radish	Shoot	Control	3	19.9	0.9265	20514				2911				164			
Radish	Shoot	Control	4	19.9	1.1874	27389				3372				183			
Radish	Shoot	Bacteria	1	19.9	0.6932	28219	37064	7527	0.20	3918	3990	481	0.12	172	165	38	0.23
Radish	Shoot	Bacteria	2	20.0	1.0097	41865				4352				186			
Radish	Shoot	Bacteria	3	19.9	1.0604	44586				3336				110			
Radish	Shoot	Bacteria	4	20.0	0.9852	33586				4352				193			
Radish	Shoot	Fungus	1	19.9	1.0051	43390	50967	6787	0.13	33161	39219	5195	0.13	12407	10432	1783	0.17
Radish	Shoot	Fungus	2	19.9	1.1958	52123				40722				8236			
Radish	Shoot	Fungus	3	19.9	1.0067	48755				37522				9916			
Radish	Shoot	Fungus	4	19.9	1.1057	59602				45473				11170			
Radish	Shoot	Biosolid	1	19.9	1.666	30601	33696	4415	0.13	3349	2947	517	0.18	83	70	14	0.20
Radish	Shoot	Biosolid	2	19.9	1.3155	38208				3334				80			
Radish	Shoot	Biosolid	3	19.9	1.3482	29277				2253				65			
Radish	Shoot	Biosolid	4	19.9	1.3712	36697				2854				53			
Radish	Shoot	Biosolid+Bacteria	1	20.0	1.561	48502	47131	2588	0.05	35603	34786	2016	0.06	9794	9402	1017	0.11
Radish	Shoot	Biosolid+Bacteria	2	19.9	1.5061	43410				31864				9376			
Radish	Shoot	Biosolid+Bacteria	3	20.0	1.7076	49200				36460				8018			
Radish	Shoot	Biosolid+Bacteria	4	19.9	1.6876	47413				35217				10418			
Radish	Shoot	Biosolid+Fungus	1	19.9	1.4681	46546	50264	5153	0.10	34402	37374	4221	0.11	9648	7308	1599	0.22
Radish	Shoot	Biosolid+Fungus	2	19.9	1.2297	47541				35059				6729			
Radish	Shoot	Biosolid+Fungus	3	20.0	1.1227	57825				43574				6032			
Radish	Shoot	Biosolid+Fungus	4	19.9	0.9917	49143				36463				6822			
Radish	Shoot	Compost	1	19.9	0.7248	42866	40605	10461	0.26	30667	28908	7755	0.27	9140	9046	958	0.11
Radish	Shoot	Compost	2	19.9	0.6952	49682				35629				7679			
Radish	Shoot	Compost	3	19.9	0.7974	44332				31603				9497			
Radish	Shoot	Compost	4	19.9	0.6325	25541				17732				9867			
Radish	Shoot	Compost+Bacteria	1	20.0	0.8459	52474	56635	4306	0.08	40184	44175	3456	0.08	6937	7366	1014	0.14
Radish	Shoot	Compost+Bacteria	2	19.9	0.8892	62118				47935				7243			
Radish	Shoot	Compost+Bacteria	3	19.9	0.7806	54055				42598				8811			
Radish	Shoot	Compost+Bacteria	4	19.9	0.7576	57893				45984				6471			
Radish	Shoot	Compost+Fungus	1	19.9	0.7179	71036	57813	9224	0.16	53272	43015	7128	0.17	9083	8254	873	0.11
Radish	Shoot	Compost+Fungus	2	19.9	0.6589	57109				42315				8471			
Radish	Shoot	Compost+Fungus	3	19.9	0.6047	50687				37507				8439			
Radish	Shoot	Compost+Fungus	4	20.0	0.8755	52419				38964				7021			

Table 60 Nutrient Concentrations in Radish Shoots Continued 2

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(RS) Biomass	(RS) P	(RS) P Avg	(RS) P Stdv	(RS) P CV	(RS) S	(RS) S Avg	(RS) S Stdv	(RS) S CV	(RS) Zn	(RS) Zn Avg	(RS) Zn Stdv	(RS) Zn CV
Radish	Shoot	Control	1	20.0	1.0405	4783	4546	708	0.16	14072	14122	6684	0.47	153	110.68	30.95	0.28
Radish	Shoot	Control	2	19.9	1.1025	5142				12355				81			
Radish	Shoot	Control	3	19.9	0.9265	3519				6992				98			
Radish	Shoot	Control	4	19.9	1.1874	4739				23069				111			
Radish	Shoot	Bacteria	1	19.9	0.6932	4456	5617	1538	0.27	17900	16059	2494	0.16	116	130.00	18.99	0.15
Radish	Shoot	Bacteria	2	20.0	1.0097	7722				15750				153			
Radish	Shoot	Bacteria	3	19.9	1.0604	4486				12647				113			
Radish	Shoot	Bacteria	4	20.0	0.9852	5802				17938				137			
Radish	Shoot	Fungus	1	19.9	1.0051	15458	16440	1688	0.10	24267	20278	2749	0.14	234	248.27	33.88	0.14
Radish	Shoot	Fungus	2	19.9	1.1958	17795				19932				211			
Radish	Shoot	Fungus	3	19.9	1.0067	14569				18391				291			
Radish	Shoot	Fungus	4	19.9	1.1057	17938				18523				256			
Radish	Shoot	Biosolid	1	19.9	1.666	5267	5050	516	0.10	12059	13965	2118	0.15	55	52.92	6.81	0.13
Radish	Shoot	Biosolid	2	19.9	1.3155	5528				14588				60			
Radish	Shoot	Biosolid	3	19.9	1.3482	4326				12531				43			
Radish	Shoot	Biosolid	4	19.9	1.3712	5080				16681				54			
Radish	Shoot	Biosolid+Bacteria	1	20.0	1.561	1805	7032	4305	0.61	2704	11648	6928	0.59	87	98.66	23.41	0.24
Radish	Shoot	Biosolid+Bacteria	2	19.9	1.5061	5470				9673				133			
Radish	Shoot	Biosolid+Bacteria	3	20.0	1.7076	11608				17592				94			
Radish	Shoot	Biosolid+Bacteria	4	19.9	1.6876	9246				16624				81			
Radish	Shoot	Biosolid+Fungus	1	19.9	1.4681	7912	8806	1038	0.12	20605	17314	3561	0.21	89	74.86	13.57	0.18
Radish	Shoot	Biosolid+Fungus	2	19.9	1.2297	8280				12807				84			
Radish	Shoot	Biosolid+Fungus	3	20.0	1.1227	10274				16168				62			
Radish	Shoot	Biosolid+Fungus	4	19.9	0.9917	8760				19677				64			
Radish	Shoot	Compost	1	19.9	0.7248	9638	8742	1906	0.22	21274	20604	2145	0.10	88	77.98	13.97	0.18
Radish	Shoot	Compost	2	19.9	0.6952	10882				17693				84			
Radish	Shoot	Compost	3	19.9	0.7974	7898				22812				82			
Radish	Shoot	Compost	4	19.9	0.6325	6550				20636				57			
Radish	Shoot	Compost+Bacteria	1	20.0	0.8459	15644	16794	2788	0.17	30148	31419	5808	0.18	71	92.48	25.59	0.28
Radish	Shoot	Compost+Bacteria	2	19.9	0.8892	17403				38620				79			
Radish	Shoot	Compost+Bacteria	3	19.9	0.7806	20343				32337				129			
Radish	Shoot	Compost+Bacteria	4	19.9	0.7576	13787				24573				91			
Radish	Shoot	Compost+Fungus	1	19.9	0.7179	7897	8866	2002	0.23	25502	22701	3424	0.15	80	80.36	2.45	0.03
Radish	Shoot	Compost+Fungus	2	19.9	0.6589	7057				25695				79			
Radish	Shoot	Compost+Fungus	3	19.9	0.6047	8849				18917				78			
Radish	Shoot	Compost+Fungus	4	20.0	0.8755	11661				20691.7233				84			

Table 61 Nutrient Concentrations in Lettuce Roots

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(LR) Biomass	(LR) Ca	(LR) Ca Avg	(LR) Ca Stdv	(LR) Ca CV	(LR) Cu	(LR)Cu Avg	(LR) Cu Stdv	(LR) Cu CV	(LR) Fe	(LR)Fe Avg	(LR) Fe Stdv	(LR) Fe CV
Lettuce	Root	Control	1	45.0	2.6686	8078	6158	2301	0.37	100.5	49	36	0.74	2956	3225	1262	0.39
Lettuce	Root	Control	2	28.1	5.273	7546				39.66				1901			
Lettuce	Root	Control	3	22.1	5.8495	6051				37.18				3105			
Lettuce	Root	Control	4	19.8	7.0831	2956				17.33				4938			
Lettuce	Root	Bacteria	1	19.9	7.5406	4050	5410	958	0.18	24.20	33	15	0.46	1991	2166	427	0.20
Lettuce	Root	Bacteria	2	22.6	5.4433	6200				54.52				1690			
Lettuce	Root	Bacteria	3	24.4	5.8489	5939				30.40				2294			
Lettuce	Root	Bacteria	4	23.1	4.7712	5454				21.79				2690			
Lettuce	Root	Fungus	1	36.8	3.7141	6604	7051	429	0.06	35.62	55	20	0.36	2971	3526	968	0.27
Lettuce	Root	Fungus	2	60.8	1.857	7090				75.33				2964			
Lettuce	Root	Fungus	3&4 Cp	59.8	3.0492	7460				54.15				4643			
Lettuce	Root	Biosolid	1&2 Cp	81.2	1.3440	10641	12759	2995	0.23	53.34	64	15	0.23	12833	12385	634	0.05
Lettuce	Root	Biosolid	3&4 Cp	61.3	2.0630	14877				73.96				11936			
Lettuce	Root	osolid+Bacte	1&2 Cp	60.9	2.3403	11359	11171	364	0.03	54.78	62	8	0.12	3463	4814	1650	0.34
Lettuce	Root	osolid+Bacte	3	67.8	2.0807	11403				70.10				4325			
Lettuce	Root	osolid+Bacte	4	80.0	1.5814	10752				60.736				6652.8			
Lettuce	Root	osolid+Fung	1-4 Cp	126.9	0.9396	12830	12830			53.97	54			4584	4584		
Lettuce	Root	Compost	1	20.0	5.8543	7635	7182	1613	0.22	25.96	31	11	0.35	1320	1639	891	0.54
Lettuce	Root	Compost	2	19.9	7.2291	5939				23.77				2968			
Lettuce	Root	Compost	3	27.1	4.2357	9270				47.74				1190			
Lettuce	Root	Compost	4	29.2	2.4989	5882				28.06				1079			
Lettuce	Root	mpost+Bact	1	20.0	6.8839	3188	3836	816	0.21	13.94	29	27	0.95	2546	1588	648	0.41
Lettuce	Root	mpost+Bact	2	19.9	4.7479	4131				13.09				1404			
Lettuce	Root	mpost+Bact	3	27.0	4.2708	4857				18.32				1265			
Lettuce	Root	mpost+Bact	4	19.9	5.5184	3167				69.24				1135			
Lettuce	Root	ompost+Fung	1	28.2	5.2588	4934	4294	807	0.19	18.34	12	4	0.36	830	806	202	0.25
Lettuce	Root	ompost+Fung	2	20.0	5.4811	4049				7.856				900.4			
Lettuce	Root	ompost+Fung	3	31.6	3.816	4935				12.24				979			
Lettuce	Root	ompost+Fung	4	21.1	4.7065	3259				10.56				516.6			

Table 62 Nutrient Concentrations in Lettuce Roots Continued 1

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(LR) Biomass	(LR) K	(LR) K Avg	(LR) K Stdv	(LR) K CV	(LR) Mg	(LR) Mg Avg	(LR) Mg Stdv	(LR) Mg CV	(LR) Mn	(LR) Mn Avg	(LR) Mn Stdv	(LR) Mn CV
Lettuce	Root	Control	1	45.0	2.6686	3977	5613	1857	0.33	3872	2905	1041	0.36	285	207	66	0.32
Lettuce	Root	Control	2	28.1	5.273	5722				3412				201			
Lettuce	Root	Control	3	22.1	5.8495	8179				2864				216			
Lettuce	Root	Control	4	19.8	7.0831	4573				1470				124			
Lettuce	Root	Bacteria	1	19.9	7.5406	5813	5317	1205	0.23	2339	2603	480	0.18	117	170	37	0.22
Lettuce	Root	Bacteria	2	22.6	5.4433	6507				3202				174			
Lettuce	Root	Bacteria	3	24.4	5.8489	5273				2757				194			
Lettuce	Root	Bacteria	4	23.1	4.7712	3676				2113				195			
Lettuce	Root	Fungus	1	36.8	3.7141	8015	5206	2463	0.47	3117	2955	370	0.13	273	247	27	0.11
Lettuce	Root	Fungus	2	60.8	1.857	3415				3216				219			
Lettuce	Root	Fungus	3&4 Cp	59.8	3.0492	4188				2532				250			
Lettuce	Root	Biosolid	1&2 Cp	81.2	1.3440	3542	3552	13	0.00	2884	4947	2918	0.59	154	208	77	0.37
Lettuce	Root	Biosolid	3&4 Cp	61.3	2.0630	3561				7010				262			
Lettuce	Root	Biosolid+Bacteria	1&2 Cp	60.9	2.3403	2313	2566	378	0.15	3284	3761	426	0.11	150	176	23	0.13
Lettuce	Root	Biosolid+Bacteria	3	67.8	2.0807	3001				4104				183			
Lettuce	Root	Biosolid+Bacteria	4	80.0	1.5814	2384				3894.4				194			
Lettuce	Root	Biosolid+Fungus	1-4 Cp	126.9	0.9396	5532	5532			3048	3048			186	186		
Lettuce	Root	Compost	1	20.0	5.8543	14174	18936	6726	0.36	2680	2381	344	0.14	119	93	32	0.34
Lettuce	Root	Compost	2	19.9	7.2291	12643				2242				123			
Lettuce	Root	Compost	3	27.1	4.2357	21980				2642				70			
Lettuce	Root	Compost	4	29.2	2.4989	26947				1960				62			
Lettuce	Root	Compost+Bacteria	1	20.0	6.8839	10436	21308	10269	0.48	1441	1597	291	0.18	151	75	51	0.68
Lettuce	Root	Compost+Bacteria	2	19.9	4.7479	21531				1657				59			
Lettuce	Root	Compost+Bacteria	3	27.0	4.2708	35040				1977				48			
Lettuce	Root	Compost+Bacteria	4	19.9	5.5184	18226				1312				42			
Lettuce	Root	Compost+Fungus	1	28.2	5.2588	10556	15407	3381	0.22	1672	1476	258	0.17	71	54	15	0.27
Lettuce	Root	Compost+Fungus	2	20.0	5.4811	17259				1582				48			
Lettuce	Root	Compost+Fungus	3	31.6	3.816	15712				1554				61			
Lettuce	Root	Compost+Fungus	4	21.1	4.7065	18099				1096.9				37			

Table 63 Nutrient Concentrations in Lettuce Roots Continued 2

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(LR) Biomass	(LR) P	(LR) P Avg	(LR) P Stdv	(LR) P CV	(LR) S	(LR) S Avg	(LR) S Stdv	(LR) S CV	(LR) Zn	(LR) Zn Avg	(LR) Zn Stdv	(LR) Zn CV
Lettuce	Root	Control	1	45.0	2.6686	2111	1976	440	0.22	2505	2309	654	0.28	255.3	218	62	0.29
Lettuce	Root	Control	2	28.1	5.273	2198				2685				236.5			
Lettuce	Root	Control	3	22.1	5.8495	2271				2708				253.6			
Lettuce	Root	Control	4	19.8	7.0831	1323				1338				124.9			
Lettuce	Root	Bacteria	1	19.9	7.5406	1486	1620	402	0.25	1502	1886	708	0.38	191.5	228	65	0.29
Lettuce	Root	Bacteria	2	22.6	5.4433	2106				2874				282.9			
Lettuce	Root	Bacteria	3	24.4	5.8489	1734				1899				281.6			
Lettuce	Root	Bacteria	4	23.1	4.7712	1153				1268				154.4			
Lettuce	Root	Fungus	1	36.8	3.7141	1867	1842	166	0.09	1999	1820	170	0.09	207.1	249	60	0.24
Lettuce	Root	Fungus	2	60.8	1.857	1664				1661				222.2			
Lettuce	Root	Fungus	3&4 Cp	59.8	3.0492	1994				1801				318.1			
Lettuce	Root	Biosolid	1&2 Cp	81.2	1.3440	2053	2911	1214	0.42	2895	2732	231	0.08	139.8	192	73	0.38
Lettuce	Root	Biosolid	3&4 Cp	61.3	2.0630	3769				2569.0				243.3			
Lettuce	Root	Biosolid+Bacteria	1&2 Cp	60.9	2.3403	1849	1992	168	0.08	2208	2256	116	0.05	129.8	156	24	0.15
Lettuce	Root	Biosolid+Bacteria	3	67.8	2.0807	2177				2388				162.0			
Lettuce	Root	Biosolid+Bacteria	4	80.0	1.5814	1949.6				2172				177.28			
Lettuce	Root	Biosolid+Fungus	1-4 Cp	126.9	0.9396	3093	3093			1868	1868			160.2	160		
Lettuce	Root	Compost	1	20.0	5.8543	2105	2841	1364	0.48	1524	1507	80	0.05	79.97	69	16	0.23
Lettuce	Root	Compost	2	19.9	7.2291	1872				1462				81.53			
Lettuce	Root	Compost	3	27.1	4.2357	2544				1430				66.34			
Lettuce	Root	Compost	4	29.2	2.4989	4844				1612				46.92			
Lettuce	Root	Compost+Bacteria	1	20.0	6.8839	1474	2472	813	0.33	1407	1640	246	0.15	63.24	59	5	0.08
Lettuce	Root	Compost+Bacteria	2	19.9	4.7479	2372				1740				52.76			
Lettuce	Root	Compost+Bacteria	3	27.0	4.2708	3453				1940				61.73			
Lettuce	Root	Compost+Bacteria	4	19.9	5.5184	2589				1473				56.73			
Lettuce	Root	Compost+Fungus	1	28.2	5.2588	2368	2705	799	0.30	952.0	947	126	0.13	62.07	54	12	0.23
Lettuce	Root	Compost+Fungus	2	20.0	5.4811	1771				772.8				52.43			
Lettuce	Root	Compost+Fungus	3	31.6	3.816	3093				995.0				64.03			
Lettuce	Root	Compost+Fungus	4	21.1	4.7065	3588				1069				37.15			

Table 64 Nutrient Concentrations in Lettuce Shoots

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(LS) Biomass	(LS) Ca	(LS) Ca Avg	(LS) Ca Stdv	(LS) Ca CV	(LS) Cu	(LS) Cu Avg	(LS) Cu Stdv	(LS) Cu CV	(LS) Fe	(LS) Fe Avg	(LS) Fe Stdv	(LS) Fe CV
Lettuce	Shoot	Control	1	19.9	2.3519	14337	11540	4403	0.38	16.4	12.18	3.81	0.31	290	256.50	68.14	0.27
Lettuce	Shoot	Control	2	19.8	2.3556	11607				9.1				202			
Lettuce	Shoot	Control	3	19.9	2.6989	14916				8.8				198			
Lettuce	Shoot	Control	4	19.9	2.83	5300				14.4				336			
Lettuce	Shoot	Bacteria	1	19.8	2.4533	8064	8798	618	0.07	7.0	6.85	0.36	0.05	133	148.07	22.43	0.15
Lettuce	Shoot	Bacteria	2	20.0	2.1091	9546				6.7				134			
Lettuce	Shoot	Bacteria	3	19.9	2.4112	8946				6.5				145			
Lettuce	Shoot	Bacteria	4	19.8	2.4215	8635				7.2				181			
Lettuce	Shoot	Fungus	1	19.9	1.8946	10788	11040	429	0.04	7.8	8.31	0.70	0.08	213	276.67	65.84	0.24
Lettuce	Shoot	Fungus	2	19.9	2.1708	10692				7.7				234			
Lettuce	Shoot	Fungus	3	20.0	1.97	11035				8.6				303			
Lettuce	Shoot	Fungus	4	19.8	1.6074	11647				9.1				357			
Lettuce	Shoot	Biosolid	1	20.0	0.8714	15678	14268	3728	0.26	14.5	11.74	3.43	0.29	207	171.27	72.58	0.42
Lettuce	Shoot	Biosolid	2	19.9	1.3056	8749				6.8				95			
Lettuce	Shoot	Biosolid	3	19.8	1.4437	16953				13.3				255			
Lettuce	Shoot	Biosolid	4	19.8	1.3377	15695				12.4				129			
Lettuce	Shoot	Biosolid+Bacteria	1	19.8	1.0627	20277	18432	2222	0.12	11.7	11.23	0.75	0.07	260	297.67	25.16	0.08
Lettuce	Shoot	Biosolid+Bacteria	2	19.9	1.0199	20072				10.1				305			
Lettuce	Shoot	Biosolid+Bacteria	3	19.9	1.3904	15539				11.6				315			
Lettuce	Shoot	Biosolid+Bacteria	4	19.9	1.0871	17839				11.5				310			
Lettuce	Shoot	Biosolid+Fungus	1	54.1	0.1958	22338	25273	4024	0.16	12.1	10.96	3.12	0.28	471	520.51	98.34	0.19
Lettuce	Shoot	Biosolid+Fungus	2	55.1	0.186	30231				11.1				490			
Lettuce	Shoot	Biosolid+Fungus	3	65.0	0.1745	26842				13.9				455			
Lettuce	Shoot	Biosolid+Fungus	4	28.9	0.3458	21679				6.6				666			
Lettuce	Shoot	Compost	1	20.0	1.9303	9970	9504	453	0.05	7.4	4.96	1.78	0.36	126	103.36	29.82	0.29
Lettuce	Shoot	Compost	2	20.0	2.4631	9752				5.0				129			
Lettuce	Shoot	Compost	3	19.9	1.0483	9349				4.0				93			
Lettuce	Shoot	Compost	4	19.9	0.843	8945				3.4				66			
Lettuce	Shoot	Compost+Bacteria	1	19.9	2.5561	13422	10649	2054	0.19	6.8	5.46	0.92	0.17	157	120.70	29.99	0.25
Lettuce	Shoot	Compost+Bacteria	2	20.0	1.7593	9309				4.8				87			
Lettuce	Shoot	Compost+Bacteria	3	19.9	0.9074	8899				4.9				110			
Lettuce	Shoot	Compost+Bacteria	4	20.0	1.5113	10965				5.4				130			
Lettuce	Shoot	Compost+Fungus	1	20.0	1.4792	6604	7459	846	0.11	3.5	3.65	0.14	0.04	70	66.56	4.92	0.07
Lettuce	Shoot	Compost+Fungus	2	19.9	1.7264	7614				3.8				71			
Lettuce	Shoot	Compost+Fungus	3	19.8	1.3672	7050				3.5				60			
Lettuce	Shoot	Compost+Fungus	4	19.8	0.8576	8566				3.8				65			

Table 65 Nutrient Concentrations in Lettuce Shoots Continued 1

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(LS) Biomass	(LS) K	(LS) K Avg	(LS) K Stdv	(LS) K CV	(LS) Mg	(LS) Mg Avg	(LS) Mg Stdv	(LS) Mg CV	(LS) Mn	(LS) Mn Avg	(LS) Mn Stdv	(LS) Mn CV
Lettuce	Shoot	Control	1	19.9	2.3519	41851	44848	9379	0.21	6429	6386	149	0.02	445.8	401.24	86.61	0.22
Lettuce	Shoot	Control	2	19.8	2.3556	39628				6186				295.2			
Lettuce	Shoot	Control	3	19.9	2.6989	39110				6384				371.2			
Lettuce	Shoot	Control	4	19.9	2.83	58804				6544				492.7			
Lettuce	Shoot	Bacteria	1	19.8	2.4533	34879	34307	1510	0.04	2378	2277	141	0.06	196.7	224.92	47.26	0.21
Lettuce	Shoot	Bacteria	2	20.0	2.1091	35192				2336				193.4			
Lettuce	Shoot	Bacteria	3	19.9	2.4112	32051				2069				215.3			
Lettuce	Shoot	Bacteria	4	19.8	2.4215	35105				2326				294.3			
Lettuce	Shoot	Fungus	1	19.9	1.8946	38799	36740	1720	0.05	2988	2994	36	0.01	324.0	309.65	25.70	0.08
Lettuce	Shoot	Fungus	2	19.9	2.1708	34904				3015				301.5			
Lettuce	Shoot	Fungus	3	20.0	1.97	37415				2946				277.5			
Lettuce	Shoot	Fungus	4	19.8	1.6074	35843				3028				335.6			
Lettuce	Shoot	Biosolid	1	20.0	0.8714	83317	62246	21126	0.34	3762	3335	830	0.25	101.6	77.20	25.85	0.33
Lettuce	Shoot	Biosolid	2	19.9	1.3056	33949				2100				41.90			
Lettuce	Shoot	Biosolid	3	19.8	1.4437	60024				3611				89.78			
Lettuce	Shoot	Biosolid	4	19.8	1.3377	71695				3867				75.49			
Lettuce	Shoot	Biosolid+Bacteria	1	19.8	1.0627	56733	58516	2786	0.05	6246	5926	376	0.06	117.6	129.63	17.92	0.14
Lettuce	Shoot	Biosolid+Bacteria	2	19.9	1.0199	56479				5382				118.0			
Lettuce	Shoot	Biosolid+Bacteria	3	19.9	1.3904	58347				6067				155.7			
Lettuce	Shoot	Biosolid+Bacteria	4	19.9	1.0871	62507				6008				127.3			
Lettuce	Shoot	Biosolid+Fungus	1	54.1	0.1958	65476	63716	11844	0.19	6412	19784	25372	1.28	118.7	156.57	27.23	0.17
Lettuce	Shoot	Biosolid+Fungus	2	55.1	0.186	52523				7835				177.0			
Lettuce	Shoot	Biosolid+Fungus	3	65.0	0.1745	57297				7057				175.8			
Lettuce	Shoot	Biosolid+Fungus	4	28.9	0.3458	79566				57832				154.7			
Lettuce	Shoot	Compost	1	20.0	1.9303	50469	40777	8165	0.20	2548	2138	303	0.14	142.9	89.50	55.85	0.62
Lettuce	Shoot	Compost	2	20.0	2.4631	36908				1999				132.5			
Lettuce	Shoot	Compost	3	19.9	1.0483	43952				2163				42.68			
Lettuce	Shoot	Compost	4	19.9	0.843	31777				1842				39.88			
Lettuce	Shoot	Compost+Bacteria	1	19.9	2.5561	46096	42916	4150	0.10	2912	2443	363	0.15	197.5	98.77	67.39	0.68
Lettuce	Shoot	Compost+Bacteria	2	20.0	1.7593	37250				2142.3				83.01			
Lettuce	Shoot	Compost+Bacteria	3	19.9	0.9074	45944				2171				47.71			
Lettuce	Shoot	Compost+Bacteria	4	20.0	1.5113	42375				2546				66.86			
Lettuce	Shoot	Compost+Fungus	1	20.0	1.4792	31422	33700	4799	0.14	1437	1550	158	0.10	45.51	50.96	11.38	0.22
Lettuce	Shoot	Compost+Fungus	2	19.9	1.7264	39085				1687				56.76			
Lettuce	Shoot	Compost+Fungus	3	19.8	1.3672	28269				1390				38.03			
Lettuce	Shoot	Compost+Fungus	4	19.8	0.8576	36025				1684				63.54			

Table 66 Nutrient Concentrations in Lettuce Shoots Continued 2

Plant	Plant Part	Treatment	Rep.	Dilution Factor	(LS) Biomass	(LS) P	(LS) P Avg	(LS) P Stdv	(LS) P CV	(LS) S	(LS) S Avg	(LS) S Stdv	(LS) S CV	(LS) Zn	(LS) Zn Avg	(LS) Zn Stdv	(LS) Zn CV
Lettuce	Shoot	Control	1	19.9	2.3519	6732	8505	1469	0.17	2879	2737	133	0.05	227	258	25	0.10
Lettuce	Shoot	Control	2	19.8	2.3556	9546				2821				248			
Lettuce	Shoot	Control	3	19.9	2.6989	9866				2615				281			
Lettuce	Shoot	Control	4	19.9	2.83	7876				2634				276			
Lettuce	Shoot	Bacteria	1	19.8	2.4533	4734	4900	246	0.05	1808	1878	89	0.05	238	233	21	0.09
Lettuce	Shoot	Bacteria	2	20.0	2.1091	5112				1924				260			
Lettuce	Shoot	Bacteria	3	19.9	2.4112	4644				1980				217			
Lettuce	Shoot	Bacteria	4	19.8	2.4215	5109				1799				217			
Lettuce	Shoot	Fungus	1	19.9	1.8946	3415	3677	386	0.10	1529	1682	178	0.11	264	283	43	0.15
Lettuce	Shoot	Fungus	2	19.9	2.1708	3562				1595				306			
Lettuce	Shoot	Fungus	3	20.0	1.97	3482				1671				233			
Lettuce	Shoot	Fungus	4	19.8	1.6074	4248				1934				330			
Lettuce	Shoot	Biosolid	1	20.0	0.8714	5448	4585	1269	0.28	2959	2505	740	0.30	81	64	19	0.30
Lettuce	Shoot	Biosolid	2	19.9	1.3056	2735				1404				36			
Lettuce	Shoot	Biosolid	3	19.8	1.4437	4780				2743				71			
Lettuce	Shoot	Biosolid	4	19.8	1.3377	5375				2914				67			
Lettuce	Shoot	Biosolid+Bacteria	1	19.8	1.0627	7816	7652	351	0.05	3556	3537	70	0.02	155	164	14	0.09
Lettuce	Shoot	Biosolid+Bacteria	2	19.9	1.0199	7126				3466				156			
Lettuce	Shoot	Biosolid+Bacteria	3	19.9	1.3904	7826				3627				185			
Lettuce	Shoot	Biosolid+Bacteria	4	19.9	1.0871	7841				3500				158			
Lettuce	Shoot	Biosolid+Fungus	1	54.1	0.1958	7105	8201	3940	0.48	3710	4041	2199	0.54	165	198	23	0.12
Lettuce	Shoot	Biosolid+Fungus	2	55.1	0.186	7967				3759				202			
Lettuce	Shoot	Biosolid+Fungus	3	65.0	0.1745	13580				7005				204			
Lettuce	Shoot	Biosolid+Fungus	4	28.9	0.3458	4153				1688				219			
Lettuce	Shoot	Compost	1	20.0	1.9303	5422	4474	667	0.15	1377	1324	180	0.14	100	70	26	0.37
Lettuce	Shoot	Compost	2	20.0	2.4631	4308				1066				81			
Lettuce	Shoot	Compost	3	19.9	1.0483	4312				1365				54			
Lettuce	Shoot	Compost	4	19.9	0.843	3855				1486				44			
Lettuce	Shoot	Compost+Bacteria	1	19.9	2.5561	4291	3926	304	0.08	1396	1172	165	0.14	78	50	19	0.38
Lettuce	Shoot	Compost+Bacteria	2	20.0	1.7593	3559				1139				40			
Lettuce	Shoot	Compost+Bacteria	3	19.9	0.9074	3859				999				38			
Lettuce	Shoot	Compost+Bacteria	4	20.0	1.5113	3994				1154				45			
Lettuce	Shoot	Compost+Fungus	1	20.0	1.4792	3404	3603	423	0.12	791	916	87	0.09	40	38	6	0.15
Lettuce	Shoot	Compost+Fungus	2	19.9	1.7264	3902				933				45			
Lettuce	Shoot	Compost+Fungus	3	19.8	1.3672	3104				990				31			
Lettuce	Shoot	Compost+Fungus	4	19.8	0.8576	4001				950				38			

Table 67 Mehlich III Concentrations in Lettuce Soils

Treatment	(M3) Ca	(M3) Ca Avg	(M3) Ca Stdv	(M3) Ca CV	(M3) Cu	(M3) Cu Avg	(M3) Cu Stdv	(M3) Cu CV	(M3) Fe	(M3) Fe Avg	(M3) Fe Stdv	(M3) Fe CV	(M3) K	(M3) K Avg	(M3) K Stdv	(M3) K CV
Control	1699	1722	33	0.02	9.8	9.9	0.08	0.01	166	164	1.74	0.01	36.6	37.4	1.17	0.03
	1745				9.9				163				38.2			
Bacteria	1690	1708	25	0.01	9.3	9.3	0.06	0.01	157	159	2.69	0.02	42.3	42.2	0.08	0.00
	1725				9.4				160				42.2			
Fungus	1683	1738	78	0.04	8.6	9.0	0.58	0.06	158	166	11.43	0.07	43.7	44.0	0.53	0.01
	1793				9.4				174				44.4			
Biosolid	4256	4418	229	0.05	8.8	9.1	0.46	0.05	141	138	4.24	0.03	86.2	85.9	0.38	0.00
	4580				9.5				135				85.6			
Biosolid+Bacteria	3497	3508	16	0.00	9.4	9.5	0.12	0.01	163	156	9.00	0.06	112.9	113.0	0.01	0.00
	3520				9.6				150				113.0			
Biosolid+Fungus	3265	3610	487	0.13	8.3	8.8	0.67	0.08	151	143	11.78	0.08	139.8	143.7	5.54	0.04
	3954				9.3				135				147.6			
Compost	2699	2616	118	0.05	8.1	7.9	0.22	0.03	183	170	18.20	0.11	152.6	146.3	8.92	0.06
	2532				7.7				157				139.9			
Compost+Bacteria	3056	2960	136	0.05	7.8	7.8	0.02	0.00	148	147	1.08	0.01	187.0	185.8	1.68	0.01
	2864				7.8				146				184.6			
Compost+Fungus	2929	2805	176	0.06	8.0	8.0	0.07	0.01	144	139	7.05	0.05	186.3	181.5	6.74	0.04
	2681				7.9				134				176.8			

Table 68 Mehlich III Concentrations in Lettuce Soils Continued

Treatment	(M3) Mg	(M3) Mg Avg	(M3) Mg Stdv	(M3) Mg CV	(M3) Mn	(M3) Mn Avg	(M3) Mn Stdv	(M3) Mn CV	(M3) P	(M3) P Avg	(M3) P Stdv	(M3) P CV	(M3) S	(M3) S Avg	(M3) S Stdv	(M3) S CV	(M3) Zn	(M3) Zn Avg	(M3) Zn Stdv	(M3) Zn CV
Control	150.6	151.1	0.66	0.00	54.7	52.3	3.41	0.07	232	232	0.08	0.00	64	65	0.84	0.01	46	47	0.79	0.02
	151.6				49.9				232				65				48			
Bacteria	146.9	149.5	3.67	0.02	57.5	58.9	2.02	0.03	220	225	7.48	0.03	77	75	2.86	0.04	45	46	1.51	0.03
	152.1				60.3				230				73				47			
Fungus	147.8	151.7	5.54	0.04	60.0	58.8	1.68	0.03	224	234	13.05	0.06	59	63	5.54	0.09	45	46	1.66	0.04
	155.6				57.6				243				67				48			
Biosolid	231.5	233.0	2.07	0.01	50.6	52.3	2.41	0.05	234	238	5.94	0.02	119	122	5.51	0.04	41	41	0.21	0.01
	234.5				54.0				243				126				40			
Biosolid+Bacteria	206.0	205.2	1.08	0.01	53.8	54.4	0.91	0.02	240	241	2.52	0.01	89	89	0.28	0.00	43	43	0.59	0.01
	204.4				55.0				243				89				44			
Biosolid+Fungus	202.3	210.1	11.03	0.05	46.8	49.5	3.85	0.08	221	231	13.71	0.06	79	85	8.02	0.09	38	41	3.59	0.09
	217.9				52.2				241				90				44			
Compost	324.7	309.8	21.04	0.07	75.5	72.7	3.87	0.05	227	226	0.88	0.00	101	94	9.63	0.10	52	50	2.41	0.05
	295.0				70.0				225				87				49			
Compost+Bacteria	349.0	343.8	7.41	0.02	76.2	72.0	5.93	0.08	210	210	0.11	0.00	100	100	0.09	0.00	54	53	1.99	0.04
	338.5				67.8				210				100				51			
Compost+Fungus	340.5	328.0	17.61	0.05	77.4	74.3	4.34	0.06	213	209	5.14	0.02	101	97	4.80	0.05	53	51	2.02	0.04
	315.6				71.2				206				94				50			

Table 69 Mehlich III Concentrations in Radish Soils

Treatment	(M3) Ca	(M3) Ca Avg	(M3) Ca Stdv	(M3) Ca CV	(M3) Cu	(M3) Cu Avg	(M3) Cu Stdv	(M3) Cu CV	(M3) Fe	(M3) Fe Avg	(M3) Fe Stdv	(M3) Fe CV	(M3) K	(M3) K Avg	(M3) K Stdv	(M3) K CV
Control	1588.02	1599	16	0.01	9.30922	9.6	0.4	0.04	165	172	10	0.059	51	50	0.72	0.014
	1610.56				9.84063745				179				50			
Bacteria	1721.02	1673	68	0.04	13.31468811	11.2	3.0	0.26	197	179	25	0.141	54	52	3.04	0.059
	1625.29				9.128415164				161				49			
Fungus	1662.01	1628	48	0.03	8.99381114	8.7	0.4	0.05	163	184	30	0.161	51	50	1.30	0.026
	1594.06				8.396969395				205				49			
Biosolid	2889.54	2859	43	0.02	9.654793426	9.3	0.4	0.05	160	152	11	0.074	87	88	0.74	0.008
	2828.75				9.031613644				144				88			
Biosolid+Bacteria	2635.34	2717	116	0.04	8.924768808	8.8	0.1	0.02	160	146	20	0.138	70	68	3.26	0.048
	2799.6				8.728635682				132				66			
Biosolid+Fungus	3139.81	3166	37	0.01	11.9896435	10.5	2.1	0.19	134	136	3	0.023	84	84	0.04	0.000
	3191.97				9.090364154				139				84			
Compost	2098.95	2074	35	0.02	7.305347326	7.3	0.0	0.01	146	144	2	0.012	127	126	1.85	0.015
	2049.03				7.25348245				143				124			
Compost+Bacteria	2190.33	2364	246	0.10	6.761335326	6.9	0.2	0.03	143	145	1	0.010	145	146	0.84	0.006
	2538.19				7.095356965				146				147			
Compost+Fungus	2374.05	2395	30	0.01	7.647940824	7.7	0.1	0.01	153	156	4	0.026	134	136	2.20	0.016
	2416.28				7.787663701				159				137			

Table 70 Mehlich III Concentrations in Radish Soils Continued

Treatment	(M3) Mg	(M3) Mg Avg	(M3) Mg Stdv	(M3) Mg CV	(M3) Mn	(M3) Mn Avg	(M3) Mn Stdv	(M3) Mn CV	(M3) P	(M3) P Avg	(M3) P Stdv	(M3) P CV	(M3) S	(M3) S Avg	(M3) S Stdv	(M3) S CV	(M3) Zn	(M3) Zn Avg	(M3) Zn Stdv	(M3) Zn CV
Control	159	160	1.10	0.007	57	64	8.97	0.141	274	286	17.31	0.061	50	51	1.06	0.021	43.2	46.4	4.60	0.099
	161				70				298				51				49.7			
Bacteria	172	166	9.24	0.056	60	63	3.46	0.055	292	289	5.21	0.018	57	55	2.24	0.040	52.8	50.7	2.96	0.058
	159				65				285				54				48.6			
Fungus	166	168	2.31	0.014	71	76	8.29	0.109	278	272	8.71	0.032	64	65	2.78	0.042	45.9	44.7	1.64	0.037
	170				82				266				67				43.5			
Biosolid	199	189	14.31	0.076	68	60	11.17	0.186	272	278	7.36	0.027	74	75	0.51	0.007	40.1	39.4	0.91	0.023
	178				52				283				75				38.8			
Biosolid+Bacteria	195	192	4.42	0.023	53	53	0.54	0.010	249	250	2.01	0.008	61	64	4.52	0.071	38.6	37.9	0.98	0.026
	189				54				251				67				37.2			
Biosolid+Fungus	195	197	1.58	0.008	55	54	1.60	0.029	263	268	7.03	0.026	82	84	2.44	0.029	54.7	46.6	11.51	0.247
	198				53				273				86				38.4			
Compost	259	255	5.26	0.021	81	81	0.30	0.004	257	258	0.53	0.002	92	92	0.67	0.007	40.1	39.2	1.22	0.031
	252				81				258				93				38.4			
Compost+Bacteria	302	309	9.04	0.029	94	101	9.19	0.091	224	232	10.84	0.047	97	100	3.51	0.035	41.6	42.6	1.42	0.033
	315				107				240				102				43.6			
Compost+Fungus	287	289	2.07	0.007	98	101	4.62	0.046	250	252	2.99	0.012	84	83	0.69	0.008	43.3	42.8	0.60	0.014
	290				104				255				83				42.4			

Table 71 Mehlich III Concentrations in Tomato Soils

Treatment	(M3) Ca	(M3) Ca Avg	(M3) Ca Stdv	(M3) Ca CV	(M3) Cu	(M3) Cu Avg	(M3) Cu Stdv	(M3) Cu CV	(M3) Fe	(M3) Fe Avg	(M3) Fe Stdv	(M3) Fe CV	(M3) K	(M3) K Avg	(M3) K Stdv	(M3) K CV
Control	1331	1331	3.76	0.003	9.83	9.83	0.600	0.061	192	192	3.85	0.020	32	32	1.01	0.032
	1336				8.98				187				30			
Bacteria	1353	1353	47.35	0.035	8.88	8.88	0.478	0.054	179	179	1.54	0.009	48	48	1.13	0.024
	1286				8.20				176				46			
Fungus	1359	1359	8.23	0.006	8.48	8.48	0.052	0.006	179	179	6.07	0.034	43	43	0.29	0.007
	1370				8.40				170				43			
Biosolid	2143	2143	43.80	0.020	8.60	8.60	0.310	0.036	123	123	3.31	0.027	55	55	1.50	0.027
	2205				9.04				118				53			
Biosolid+Bacteria	2326	2326	37.34	0.016	8.07	8.07	0.927	0.115	114	114	4.00	0.035	104	104	2.01	0.019
	2273				9.38				120				101			
Biosolid+Fungus	2400	2400	10.38	0.004	8.22	8.22	0.010	0.001	119	119	3.14	0.027	114	114	2.78	0.024
	2415				8.20				114				110			
Compost	2086	2086	73.66	0.035	7.37	7.37	0.443	0.060	142	142	3.42	0.024	86	86	6.82	0.079
	2190				7.99				138				96			
Compst+Bacteria	2310	2310	56.47	0.024	7.10	7.10	0.118	0.017	133	133	1.55	0.012	99	99	3.08	0.031
	2390				7.26				131				103			
Compost+Fungus	2294	2294	30.18	0.013	7.94	7.94	0.195	0.025	143	143	4.07	0.028	95	95	3.29	0.035
	2252				7.66				138				90			

Table 72 Mehlich III Concentrations in Tomato Soils Continued

Treatment	(M3) Mg	(M3) Mg Avg	(M3) Mg Stdv	(M3) Mg CV	(M3) Mn	(M3) Mn Avg	(M3) Mn Stdev	(M3) Mn Cv	(M3) P	(M3) P Avg	(M3) P Stdv	(M3) P CV	(M3) S	(M3) S Avg	(M3) S Stdv	(M3) S CV	(M3) Zn	(M3) Zn Avg	(M3) Zn Stdv	(M3) Zn CV
Control	139	139	0.96	0.01	92	91	1.69	0.02	299	299	0.4	0.001	54	54	3.86	0.07	40	40	0.65	0.016
	137				90				299				60				39			
Bacteria	138	138	2.12	0.02	89	86	3.31	0.04	316	316	20.1	0.064	60	60	3.45	0.06	44	44	3.88	0.089
	135				84				287				55				38			
Fungus	138	138	2.16	0.02	106	105	1.30	0.01	298	298	0.7	0.002	72	72	0.21	0.00	39	39	0.17	0.004
	142				104				297				71				39			
Biosolid	141	141	1.21	0.01	60	58	2.77	0.05	284	284	1.9	0.007	60	60	2.58	0.04	32	32	0.02	0.001
	143				56				281				63				32			
Biosolid+Bacteria	158	158	1.00	0.01	59	59	0.57	0.01	268	268	11.5	0.043	91	91	10.04	0.11	32	32	1.19	0.037
	157				60				284				77				34			
Biosolid+Fungus	165	165	2.02	0.01	55	55	0.26	0.00	278	278	0.7	0.003	74	74	6.93	0.09	33	33	0.19	0.006
	162				55				279				84				33			
Compost	244	244	12.90	0.05	90	92	3.08	0.03	273	273	10.2	0.037	101	101	2.10	0.02	38	38	1.74	0.046
	262				94				288				104				40			
Compst+Bacteria	277	277	8.85	0.03	89	94	6.75	0.07	255	255	6.2	0.024	96	96	8.98	0.09	39	39	1.43	0.036
	290				99				263				109				41			
Compost+Fungus	278	278	8.14	0.03	100	96	5.30	0.05	274	274	1.0	0.004	87	87	0.37	0.00	40	40	0.08	0.002
	266				93				273				86				40			