EFFECTS OF COMPOST, LEGUME COVER CROPPING AND
VERMICOMPOST EXTRACT FOLIAR APPLICATIONS
ON NUTRITION AND YIELD OF WASHINGTON
NAVEL ORANGES

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by
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TITLE: Effects of Compost, Legume Cover Cropping and Vermicompost Extract Foliar Applications on Nutrition and Yield of Washington Navel Oranges

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ABSTRACT

Effects of Compost, Legume Cover Cropping and Vermicompost Extract Foliar Applications on Nutrition and Yield of Washington Navel Oranges

William Payton Carling

An experiment was conducted to test the effects of four treatments on Washington navel orange (*Citrus sinensis*) trees in regards to nutrient content of the leaves and fruit, soil nutrient content and properties, and fruit yield. The four treatments included: compost (C) and vermicompost extract foliar (VEF) applications, legume cover cropping (LCC) and VEF applications, VEF applications, and a control. The treatments were implemented from February 2010 to April 2011 and sampling occurred in May 2011. Fruit Growers Laboratory, Inc. (FGL) conducted the soil, leaf, and fruit analyses. The test site was located in San Isidro, Baja California Sur, Mexico.

The compost used was made onsite with livestock manure, carbon-based farm waste, and water, and applied around the drip-lines of 8 WNO trees once every two months. The vermicompost and vermicompost extract was made onsite by introducing red wiggler worms (*Eisenia fetida*) into horse manure, allowing 1 month for casting content to build up, and collecting the extract as water was filtered through the material. Vermicompost extract was applied using a backpack foliar sprayer on 8 WNO trees twice a month. The legume cover crop treatment consisted of two plantings at a rate of approximately 72 seeds per square foot around the drip-lines of 8 WNO trees. Black-eyed peas (*Vigna unguiculata*) were planted in April 2010 and minimally incorporated

using a hoe and shovel in August 2010. Fababeans (*Vicia faba*) and dry peas (*Pisum sativum*) were planted in January 2011 and minimally incorporated into the soil in March 2011. WNO leaf and soil analyses were compared to FGL optimum ranges.

The C+VEF treatment showed trends of increased soil and leaf nitrogen, phosphorus, potassium, calcium, zinc, and copper levels and improved soil properties by raising soil organic matter percentage, saturation percentage, and moisture percentage. The control treatment had low or deficient values in these nutrients and soil properties. The LCC+VEF treatment increased nitrogen in the soil and leaf content but decreased organic matter percentage. The VEF treatment increased nitrogen and potassium content in the leaf but increased sodium beyond FGL optimum range. The C+VEF treatment had the highest yield and the greatest amount of nutrients removed as a result of yield. The C+VEF treatment had more available nutrients in the soil for WNO tree uptake and future crops.

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CHAPTER 1

Introduction

In 1996 the author bought a farm in La Purisima, Baja California Sur, Mexico. The existing orchards on the farm consisted of navel oranges (*Citrus sinensis*), mission figs (*Ficus carica*), dates (*Phoenix dactyifera*), mangos (*Mangifera indica*), grapes (*Vitis vinifera*), guavas (*Psidium guajava*), and Carrizo (*Arundo donax*). An acre of open field was under cultivation. In order to properly maintain a balance in nutrient cycling for optimum crop production, fertility amendment strategies needed to be implemented. The intent of this thesis is to quantify the effect of compost applications, legume cover cropping, and foliar applications of vermicompost extract on nutrient cycling of the Washington navel orange trees.

During the experimental time period two major hurricanes passed through the region resulting in crop and structural damage on the farm and changes in soil conditions of the original test site. After the hurricanes, another test site was established and the fertility strategies implemented.

CHAPTER 2

Literature Review

This literature review covers Washington navel orange physiology, compost applications, vermicompost extract applications, and legume cover cropping.

Washington Navel Orange (Citrus sinensis)

Washington navel oranges (WNO) are grown in nearly all citrus growing regions of the world and are commercially important in Australia, the United States of America, Morocco, Mexico, South Africa, and Spain. The WNO originated in Brazil and was brought to Washington D.C. where it was distributed throughout the world in 1986 and became the most widely grown navel cultivar on earth. The fruit is important to fresh fruit markets worldwide for its high quality and the fact that the fruit contains the compound limonin which when oxidized instills bitterness to the juice thus limiting fruit processing. The oval or oblong shape fruit is seedless due to pollen and ovule sterility. The cultivar produces its highest quality fruit in Mediterranean climates and fairs well in hot, arid climates (Davies and Albrigo, 1998).

Nutrients

The twelve macro- and micronutrients required for tree growth and yields, besides the readily available C, O, and H, are macro-elements N, P, K, Mg, Ca, S, and micro-elements Mn, Cu, Zn, B, Fe, and Mo. An optimum quantity of each element is necessary for optimum metabolic functioning and consistently high fruit production (Davies and Albrigo, 1998).

Nutrient uptake fluctuates during the different phases of fruit development (Storey and Treeby, 2001). During phase 1 cell division takes place and almost all cells of mature fruit are created. Phase 1 begins just after bloom and lasts 1 to 1 ½ months. Cell differentiation occurs during phase 2 and all the different fruit tissues are established. The duration of phase 2 is roughly 4 months for navel oranges. Phase 3 is the cell enlargement phase where cells increase in volume up to 1,000 times, and there is a rapid increase in fruit size and the percentage of total soluble solid. The duration of phase 3 for navel oranges fluctuates with climate and conditions from 3 to 4 months in the lowland tropics of Cartagena, Colombia to 10 months in the semiarid subtropical coastal climate of Santa Paula, California. Phase 4 is the maturation phase in which growth levels off and the total soluble solids increase and total acidity rapidly decreases. Fruit changes color from green to orange during the end of phase 4. In Mediterranean climates phase 4 can be 9 or 10 months and 1 or 2 months in the humid tropics. The time from bloom to fruit containing acceptable TSS:TA ratios for harvest differs from 6 or 7 months in the humid tropics to 14 to 16 months in Mediterranean climates. Soil moisture and

temperature are the determining factors (Davies and Albrigo, 1998). Nutrient uptake in the fruit occurs most rapidly during phase 1 and early phase 2 (Storey and Treeby, 2001).

Nitrogen

The optimum range of nitrate-nitrogen in the soil is 40 to 80 pounds per acre-foot (lbs/AF) and 2.6% to 2.8% in leaf tissue (Fruit Growers Laboratory, Inc., 2011). Of all the elements, nitrogen has the greatest impact on tree growth and fruit production (Davies and Albrigo, 1998). Additional nitrogen increases the amount of fruit and flowering produced, but not the size. Nitrogen is found in all amino acids and proteins of the tree. Uptake of nitrogen, similar to all macro- and micronutrients, can occur through the leaf surface or roots and translocates through the transpiration stream throughout the tree. Fruit harvest accounts for yearly nitrogen removal per acre ranging from 20 kg to 60 kg in average to high yields and 100 kg in maximum yields (Smith, 1966a).

Phosphorus

Phosphorus is a major component in cell energy systems and cell structure (Davies and Albrigo, 1998). The optimum range of phosphorus in the soil is 140 to 280 lbs/AF and 0.12% to 21% in the leaf tissue (Fruit Growers Laboratory, Inc., 2011).

Potassium

Potassium is essential for regulating cell ionic balance and ensuring proper fruit size and peel thickness. The optimum range of potassium in the soil is exchangeable 680 to 4,100 lbs/AF and 94 to 470 lbs/AF in solution. The optimum range in leaf tissue is

0.70% to 3.3%. Potassium plays a key role in fruit quality. Nitrogen to potassium ratios between 1.6 and 2.2 are the optimum for fruit size with leaf N greater than 1.8% and P greater than 0.9%. Optimum ratios for overall fruit yield are between 2.4 to 3.0 (Davies and Albrigo, 1998). A navel orange crop of 100 kg contains 200 g of potassium (Storey and Treeby, 2001).

Calcium

The optimum range of calcium in the soil is 18,000 to 23,000 lbs/AF exchangeable and 160 to 640 lbs/AF in solution (Fruit Growers Laboratory, Inc., 2011). Optimum range in leaf tissue is between 3% and 5.5%. Calcium comprises 20% of the elemental content of a mature citrus tree, thus it is a prevalent element. Calcium is involved in metabolite transport, enzyme functioning, and cell wall structural material (Davies and Albrigo, 1998).

Magnesium

Magnesium is necessary for many enzyme reactions within the tree (Davies and Albrigo, 1998). A navel orange crop of 100 kg contains 60 to 70 g of magnesium (Storey and Treeby, 2001). The optimum range of magnesium in the soil is 1,800 to 3,500 lbs/AF exchangeable and 73 to 220 lbs/AF in solution (Fruit Growers Laboratory, Inc., 2011).

Sodium

The optimum range of sodium in the soil is 0 to 1,700 lbs/AF exchangeable and 0 to 1,200 lbs/AF in solution (Fruit Growers Laboratory, Inc., 2011).

Sulfur

Sulfur is a necessary part of proteins and enzymes in trees and is rarely deficient in citrus (Davies and Albrigo, 1998). The optimum range of sulfate in the soil is 120 to 3,800 lbs/AF (Fruit Growers Laboratory, Inc., 2011).

Zinc

Zinc deficiency is associated with the occurrence of citrus blight, citrus variegated chlorosis and smaller than normal leaves (Davies and Albrigo, 1998). The optimum range of zinc in the soil is 4 to 160 lbs/AF and 25 to 200 ppm in leaf tissue (Fruit Growers Laboratory, Inc., 2011).

Manganese

The optimum range of manganese in the soil is 6.0 to 240 lbs/AF and 25 to 200 ppm in leaf tissue. Manganese becomes complexed and unavailable in high pH soils. Yellow patches between veins of young growing leaves are signs of manganese deficiency (Davies and Albrigo, 1998).

Iron

The optimum range of iron in the soil is 40 to 160 lbs/AF and 60 to 200 ppm in leaf tissue. Deficiency symptoms are chlorosis with a fine network of green veins in the leaf. Iron chelate can be applied to trees in high pH soil as a foliar spray or root feed (Davies and Albrigo, 1998).

Copper

The optimum range of copper in the soil is 1.2 to 41 lbs/AF and 5 to 40 ppm in leaf tissue. Copper is important in the early development of citrus trees.

Boron

Boron has a narrow range between optimum, deficiency, and toxicity. The optimum range of boron in the soil is 1.2 to 8.4 lbs/AF and 31 to 300 ppm in leaf tissue.

Chloride

The optimum range of chloride in the soil is 14 to 660 lbs/AF.

All optimum nutrient ranges are the recommended levels by Fruit Growers Laboratory, Inc. as of 2011 and are based on experimentations by Smith (1996a, 1996b).

Compost Applications

The process of composting originated when the first forms of plant life appeared on earth and perished, thus completing their life-cycles, and microorganisms found

niches in the decaying processes of the leftover material. Microorganisms turn dead plant and animal matter into humus and humus provides a medium and a slow release of nutrients for plant life. Early human agriculturalists discovered the soil enriching qualities of finished compost, or humus, not long after discovering tilling, planting, and irrigation (Rodale, 1971). Today, compost is one of the principal soil amendments used in organic agriculture and by gardeners world-wide.

Truly finished compost is humus. Humus is the product of the decomposing and synthetic activities of soil microorganisms on dead organic matter (DOM). DOM contains the optimum organic carbon to nitrogen ratio (between 10 to 1 and 30 to 1), and is necessary for microbial development. The microbial decomposition of DOM under suitable conditions of aeration and humidity produces brown or black organic complexes leaving no trace of the original material. Microbial protoplasm is synthesized and new compounds are formed. Humus contains compounds of carbon, hydrogen, oxygen, nitrogen, phosphorus, sulfur, and lesser amounts of the other elements (Alexander, 1977).

Compost applications raise the organic matter content of soil thus increasing the cation-exchange capacity which is the nutrient reservoir for growing plants (Gaskell et al., 2000). Compost applications improve soil physical properties by decreasing bulk density and improving aggregate stability (Diacono and Montemurro, 2010). Soil aeration, drainage, and water holding capacity improves with an increase of soil organic matter (Gaskell et al., 2000). Ingham (2005) states that a 1% increase of organic matter raises water content of the soil by 27,000 gallons per acre. Populations of vesicular arbuscular mycorrhizal (VAM) fungi rise as an effect of compost applications (Douds et al., 1997). Compost and vermicompost were found to improve soil properties by

increasing pH, nutrient, and organic matter content in degraded tropical soils (Jouquet et al., 2011).

Vermicompost contains higher VAM counts than composts without earthworms. As DOM is ingested and passes through the guts of earthworms, VAM populations are increased and dispersal is enhanced. VAM fungi have a symbiotic relationship with plant roots in regards to nutrient exchange and water availability (Edwards and Bohlen, 1996). In the citrus variety Jamhiri, a direct correlation was found between the presence of VAM in the roots and tree growth. Normal trees had 50% more VAM infection than stunted trees (Weir et al., 1978). Compost and vermicompost soil amendments increased leaf content of the nutrients Ca, Mg, Mn, Fe, Zn, and Cu in greenhouse lettuce (Hernandez et al., 2010).

Composting animal manures stabilizes nutrients by creating humus, a safe fertilizer which can be applied directly to growing crops (Kuepper, 2003). Animal manures must be managed properly to avoid nutrient leaching into surface or ground water systems causing eutrophication. Manure in hypoxic and anaerobic conditions stimulates microbial growth of human pathogens as well as plant pathogens (Kuepper, 2003).

Vermicompost Extract

Vermicompost extract is obtained by the passing of water through worm castings. Nutrients and microorganisms are extracted from the castings and the liquid is applied to plants as a foliar or root feeder. A brewing process takes place as the extraction is collected. The microorganisms continue to respire, metabolize, and reproduce.

Microbial growth is stimulated with aeration and the addition of food. It is important for the extraction to be aerobic in order to retain the microbial species beneficial to plants (Ingham, 2005).

Ingham (2005), states that quality compost, necessary for quality extract, contains between 26,000 and 500,000 species of microorganisms in one gram. A complex ecosystem exists where bacteria and fungi consume DOM, immobilizing nutrients, and microarthropods, nematodes, and protozoa consume bacteria and fungi. Nutrients are mobilized by excretions of the upper trophic level species and are available for plant uptake and other microbial life.

According to Ingham (2000), as a foliar application, vermicompost extract benefits plants by creating conditions which stimulate leaf surface gas concentrations allowing stomata to open and remain open for respiration and plant uptake of nutrients. Nutrients in the extract remain on the leaf surface and release slowly over time for plant uptake. Beneficial microorganisms in the extract inhabit infection sites and leaf surfaces on the plant outcompeting pathogens. The colonization of beneficial microorganisms protects the plant from pathogenic invading species and provides an immediate and slow release source of nutrients. Produce nutritional quality is thusly enhanced (Ingham, 2005).

In an experiment conducted with pak choi (*Brassica rapa*), vermicompost extract applications increased plant production, mineral nutrients, antioxidant activity and total carotenoids (Plant et al., 2009). Aerated and non-aerated extract performed equally. Foliar applications of vermicompost extract were found to increase leaf area and fruit

yield of strawberry (*Fragaria nananassa*) plants. Strawberry fruit yield was enhanced by a reduction of albinism, fruit malformation, and grey mold (Singh et al., 2009).

Legume Cover Crops

Planting winter and summer cover crops, living mulches, and forage crops are key management practices in sustainable organic agricultural systems. These practices increase soil organic matter, microbial activity, and nutrient content, and work to suppress weeds and pests. Nitrogen-fixing legumes incorporated into the cropping system add nitrogen which becomes available for plant uptake approximately one month after tillage (Sullivan, 2003).

In 1915 the New Mexico Agriculture Experiment Station published a paper recognizing the need for replenishment of soil organic matter and nutrients in fruit orchards. The station reported on an experiment conducted which tested the suitability and logistics of different cover crops planted in apple orchards located in southern New Mexico. It was determined that planting and tilling in cover crops annually can maintain soil fertility in fruit orchards (Garcia, 1915).

An experiment conducted in a Mediterranean climatic region of Chile found that annual cover cropping of clover mixes in vineyards resulted in optimum nitrogen levels for crop production (Ovalle et al., 2010).

CHAPTER 3

Methods and Materials

Site Description

The site of the experiment is located in San Isidro, Baja California Sur, Mexico. San Isidro is located in the Cadegomo river valley, 26 degrees north latitude and 15 kilometers inland from the Pacific Ocean. The valley contains approximately 211 hectares of irrigated farmland and 153 individual farms. Irrigation canals run down the valley originating at two different dams. A karst system of river water flow surfaces throughout the valley forming many lagoons.

The desert climate of the region offered an average annual rainfall from 2006 to 2010 of 118.2 millimeters. The majority of precipitation occurred during late summer and early fall tropical storm and hurricane events. On September 2nd and 3rd of 2009, 196.3 mm of rainfall was accumulated in 24 hours during the passing of hurricane Jimena. Winter, spring, and early summer received little or no precipitation (Table 1).

Temperature fluctuations during the years 2006 to 2010 ranged from 0°C to 46°C. Daily fluctuations between nighttime lows and daytime highs of 25°C to 30°C were common (Table 1).

The loamy soil of the valley is alluvial in formation with parent material of limestone and igneous rock. For WNO production the soil is low in nitrogen,

Table 1. *Temperature and Rainfall Data of La Purisima, Baja California Sur, Mexico. La Purisima Weather Station, Comundo Municipal Census.*

Mean Monthly Temperature (°C)												
Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2004	16.7	17.2	20.5	20.5	22.8	24.5	29.4	29.7	28.9	23.4	19.8	19.8
2005	18.6	18.0	18.6	21.4	22.0	24.2	29.3	29.7	30.7	24.4	21.9	21.9
2006	18.5	18.8	18.5	21.2	21.8	26.9	30.4	31.0	28.3	25.5	23.1	23.1
2007	15.1	17.7	20.6	19.8	21.2	25.1	28.1	29.3	28.5	25.2	21.4	21.4
2008	17.6	18.1	19.3	20.2	20.1	26.1	28.7	29.4	28.5	25.6	20.6	20.6
2009	17.2	18.9	20.1	19.5	21.4	23.9	29.8	29.6	27.8	24.5	21.4	17.2
2010	18.9	18.2	19.2	20.5	22.0	24.5	26.7	30.5	29.5	23.3	20.5	
Maximum Monthly Temperature (°C)												
Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2004	32	35	39	38	39	42	44	44	43	41	39	39
2005	24	31	34	40	39	41	45	45	44	41	38	38
2006	37	38	41	44	39	44	43	44	41	44	41	41
2007	33	39	39	35	40	43	42	43	42	41	39	39
2008	37	41	40	40	41	46	43	42	42	42	38	38
2009	35	42	43	40	40	40	43	43	43	43	38	32
2010	35	35	39	38	39	42	40	44	43	43	40	
Minimum Monthly Temperature (°C)												
Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2004	3	3	5	1	8	9	14	15	13	8	3	3
2005	3	4	4	5	6	9	17	15	15	10	6	6
2006	0	3	2	4	7	11	17	19	15	9	4	4
2007	1	3	5	5	8	9	18	17	15	10	6	6
2008	1	2	2	6	6	8	17	20	11	12	6	6
2009	3	3	5	5	8	8	12	18	17	8	5	3
2010	4	4	7	7	5	9	11	19	11	9	2	
Monthly Precipitation (mm)												
Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2004	0	0	0	0	0	0	5.5	0	53.1	0	0	0
2005	15.9	23.0	7.3	0	6.4	0	4.7	0	0	0	0	0
2006	0	0	0	0	0	0	8.0	7.4	43.5	83.4	0	0
2007	0	0	0	0	0	0	0	3.0	12.5	0	21.2	21.2
2008	5.4	0	0	0	0	0	0	28.5	182.4	0	7.9	7.9
2009	0	0	0	0	0	0	5.7	4.2	196.3	52.2	0	7.0
2010	9.4	2.1	0	0	0	0	0	25.4	0	0	0	

phosphorus, potassium, and zinc. The soil is alkaline with a pH of 8.17. Soil organic matter is low at approximately 1.41% (Fruit Growers Laboratory, Inc., 2011).

The valley holds a diversity of agricultural enterprises. Livestock is the most commercially important. The valley and outlying ranchland contain 4,098 head of cattle (*Bos primigenius*), 15,776 goats (*Capra aegagrus hircus*), and 257 horses (*Equus ferus caballus*). The 268 pigs (*Sus scrofa domesticus*) and 1,791 chickens (*Gallus gallus Domesticus*) are raised mainly for local consumption. The orchard cultivars include: 95 hectares of date palms (*Phoenix dactylifera*), 20 hectares of oranges (*Citrus sinensis*), 11 hectares of mangos (*Mangifera indica*), 13 hectares of figs (*Ficus carica*), and 25 hectares of ‘Tlaco’ palms (*Erythea brahea brandegeei*). The 2008 Census also recorded: 10 hectares of guavas (*Psidium guajava*), 7 hectares of grapes (*Vitus vinifera*), 5 hectares of avocados (*Persea amerinana*), 4 hectares of sugar cane (*Saccharum officinarum*), 2 hectares of olives (*Olea europaea*), and 13 hectares of various fruit (Comundu Municipal Census, 2008). The main annual crops are: fava beans (*Vicia faba*), peas (*Pisum sativum*), onions (*Allium cepa*), garlic (*Allium sativum*), corn (*Zea mays*), tomatoes (*Solanum lycopersicum*), beans (*Phaseolus lunatus*), sorghum (*Sorghum bicolor*), watermelons (*Citrullus lanatus*), squash (*Cucurbita moschata*), and alfalfa (*Medicago sativa*) (Comundu Municipal Census, 2008).

The experiment took place in the WNO orchard of Raul Antonio Miranda Arce, or “Timy” as everyone calls him. Timy’s farm, located in San Isidro, is 6 hectares and its enterprises reflect the diversity of the valley. He owns a herd of roughly 100 head of cattle. Eighty-five animals graze on his 100 hectare ranch and 15 are corralled at the farm in preparation for market. It was from these corrals that manure was collected for

compost pile construction. Timy keeps 2 horses, 15 goats, 4 pigs, 3 milking cows, and chickens at the farm. Two hectares of the farm are fields for annual crops. Timy plants corn, beans, peas, onions, tomatoes, sorghum, and watermelon. The orchards grow dates, mangos, assorted citrus, guavas, 'Tlaco' palms, and figs. The WNO orchard is alley cropped with yellow (*Melilotus officinalis*) and white sweetclover (*Melilotus alba*) and buffelgrass (*Pennisetum ciliare*) used for animal feed.

The irrigation regime hinges on the rotation system of canal water running through the valley. The farm is ditch irrigated every 2 to 3 weeks depending on seasonal fluctuations in temperature and photoperiod. Irrigation water suitability for WNO production was assessed as fair by FGL (Appendix A, page 70). Irrigation water was sampled in May 2011, and its analysis is presented in Table 2.

Amendment Preparations and Applications of Treatments

Compost piles were constructed on site using the goat, cattle, and horse manures of the farm corrals and carbon-based materials of grasses and leaves from the farm. The bases of the piles were 5 feet wide and 9 feet long and dug 5 inches into the ground to retain moisture. A 3-inch layer of carbon-based material was spread at the base to begin the pile. The carbon layer was followed by a 1-inch layer of manure. The process of layering 3 inches of carbon and 1 inch of manure was continued until the pile reached 4 feet high. Water was added throughout the layering process, as well as a small amount of farm soil (Rodale, 1971). The piles composted for 1 month and then were turned. The compost was finished and ready for application 1 month after being turned. The manure

Table 2. *Irrigation Water Analysis of San Isidro, Baja California Sur, Mexico*

Test Description	Pounds Per Acre-Foot
Calcium	60
Magnesium	52
Potassium	11
Sodium	310
Carbonate	0
Bicarbonate	600
Sulfate	52
Chloride	330
Nitrate	0
Fluoride	1
Boron	1.1
Copper	0
Iron	0
Manganese	0.054
Zinc	0.11
TDS by Summation	1,400
pH	8.2
E.C.	766 umhos/cm
SAR	4.3 mg/L

mix was $\frac{1}{2}$ to $\frac{3}{4}$ goat manure and equal parts horse and cattle. The carbon material in raw form was added $\frac{3}{4}$ of the time and shredded material $\frac{1}{4}$. The compost was analyzed as an amendment by FGL (Table 3).

The first compost pile was constructed by December 8, 2009 and applied February 20, 2010. Each of the eight replicate WNO trees received 9 cubic feet of compost spread evenly around the tree from trunk base to drip-line on the first application; 6 cubic feet of compost was applied in the same manner thereafter. Compost was applied once every two months ending in April 2011 at a rate of approximately

Table 3. *Compost Amendment Analysis and Total Pounds of Nutrient Applied per Washington Navel Orange Tree in the C+VEF Treatment of the Experiment. C+VEF stands for compost and vermicompost extract foliar.*

Constituent	Pounds Per Ton	Pounds Applied Per Tree
Nitrogen	15.9	1.16
Phosphorus	20.8	1.51
Potassium	15.7	1.14
Chloride	3.24	0.23
Sodium	3.46	0.25
Boron	0.0564	0.004
Calcium	46.6	3.4
Magnesium	8.23	0.6
Zinc	0.0591	0.0043
Manganese	0.306	0.022
Iron	4.05	0.256
Copper	0.0172	0.000125
Soil Properties		
Salinity (EC)	16.4 mmhos/cm	
pH	7.52	
Moisture (%)	27.9	
Organic Matter	16.3% dried	11.8% as received
Ash (%)	83.7% dried	60.3% as received
Bulk Density	797 lbs/yd ³	
Carbon	9.7% dried	6.83% as received
Carbon:Nitrogen Ratio		8.61

28,289 pounds per acre. Three cubic feet of vermicompost was mixed with 3 cubic feet of compost and applied in June 2010 and October 2010 (see Table 4).

In following unpublished practices, two vermicompost tables were constructed consisting of plywood tops and 10-inch high wooden sides lined with thin plastic. The tables had legs 3 feet high with a 4% slope. The lower ends were not covered in plastic

Table 4. *Vermicompost Amendment Analysis*

Constituent	Pounds Per Ton	
Nitrogen	15.9	
Phosphorus	13.3	
Potassium	10.5	
Chloride	1.84	
Sodium	2.33	
Boron	0.063	
Calcium	23.7	
Magnesium	7.65	
Zinc	0.041	
Manganese	0.211	
Iron	2.12	
Copper	0.0139	
Soil Properties		
Salinity (EC)	10.1 mmhos/cm	
pH	8.39	
Moisture (%)	59.20%	
Organic Matter	40.8% dried	16.6% as received
Ash (%)	59.2% dried	24.2% as received
Bulk Density	937 lbs/yd ³	
Carbon	23.6% dried	9.63% as received
Carbon:Nitrogen Ratio		12.1

to allow water to flow out and be collected in barrels. Horse manure 8 inches thick was filled onto each table and watered twice heavily before the worms, *Eiseia fetida*, were introduced. The worms were allowed to feed and reproduce for 1 month before extract was collected for application. The extract was mixed with water at a 1 to 1 ratio and applied to the trees with a 5-gallon Solo backpack foliar sprayer.

Vermicompost extract applications commenced on April 2, 2010 and were applied every two weeks through April 2011. The extract was applied to the 24 WNO

trees included in the C+VEF, LCC+VEF, and VEF treatments. Thirty gallons of VEF was sprayed on each WNO tree in the course of the experiment. Vermicompost extract was analyzed by FGL (Table 5).

The legume cover crop (LCC) treatment consisted of two plantings. On April 20, 2010 black-eyed pea (*Vigna unguiculata*) seed was planted and the above ground biomass incorporated into the soil on August 7, 2010 with a machete, hoe, and shovel at a shallow depth so as not to disturb tree roots. On January 5, 2011 faba bean (*Vicia faba*) and dry pea (*Pisum sativum L.*) were planted and both were turned in on March 31, 2011. The LCC seed was hand broadcasted at the base of the trees from trunk to drip-line at a rate of roughly 72 seeds per square foot.

Sampling Procedures

The experiment consisted of four treatments: compost and vermicompost extract foliar (C+VEF) applications, legume cover crop, and VEF applications (LCC+VEF), VEF applications, and a control. Each treatment had 8 replicates; one replicate equaled one WNO tree. Leaf, soil, and fruit samples were taken and analyzed by FGL after the treatments had been implemented for one year. Sampling methods were based on FGL's protocol (Fruit Growers Laboratory, Inc., 2011).

Leaf samples were taken on May 23, 2011. Ten leaves were taken from each WNO experiment tree and sent to FGL for analysis as 4 composite samples representing each of the treatments. The leaves taken were from non-fruiting, non-flushing terminal

Table 5. *Vermicompost Extract Analysis and Pounds of Nutrient Applied per Washington Navel Orange Tree in the VEF Treatment of the Experiment. VEF stands for vermicompost extract foliar.*

Test Description	Pounds Per Acre-Foot	Pounds Applied Per Tree
Calcium	340	0.36
Magnesium	330	0.35
Potassium	5,300	5.67
Sodium	2,100	2.24
Carbonate	160	0.17
Bicarbonate	8,800	9.4
Sulfate	820	0.88
Chloride	4,700	5.02
Nitrate	730	0.78
Fluoride	0	0
Boron	5.4	0.0057
Copper	0.14	0.00014
Iron	1.8	0.0019
Zinc	0.6	0.00064
TDS	2,300	2.46
pH	8.3	
E.C.	11,500 umhos/cm	
SAR	12 mg/l	

shoots and washed before transport. Samples were refrigerated and sent to FGL two weeks after sampling.

Soil samples were taken on April 27, 2011. Core samples 18 inches deep were taken at the drip-line of each WNO tree in the experiment. Composite samples representing each of the four treatments were mixed in a bucket and one quart of soil was then submitted for analysis.

All fruit from the 32 WNO trees was harvested in late April, counted, and weighed. The data was statistically analyzed using a one-way analysis of variance to

determine differences in harvest quantities and fruit sizes between the treatments. Mean separation was done using the Tukey-Kramer HSD. Tree height and circumference were measured in order to attempt to separate tree size from fruit yield results. Each tree height was determined with a measuring tape attached to a pole. While one person eyed the top of the tree with the top of the pole, another person brought the two to level, then the tree height from the ground to the top was recorded. Tree circumference was measured by placing a rope around the drip-line, marking the spot in the rope where the end met the circumference completion, then straightening out the rope and measuring it in meters. Two oranges from each treatment were analyzed for nutrient content by FGL and the data was charted. The very small sample was the result of the complete sample being confiscated at the US/Mexico border by U.S. Homeland Security border officials.

CHAPTER 4

Results and Discussion

Soil and Leaf Analysis

The important trends demonstrated by the experiment were an increase in soil nitrogen, phosphorus, potassium, calcium in solution, zinc, moisture percentage, saturation, and organic matter percentage by the C+VEF treatment (Table 6.). The control treatment had low or deficient values in these soil nutrients and soil qualities. The effects on soil nutrient levels and soil properties resulting from the C+VEF treatment suggest greater availability of water and nutrients for WNO tree uptake year round.

Leaf nutrient analysis showed increases in nitrogen, potassium, and zinc by the C+VEF treatment compared to the control (Table 7). The VEF and LCC+VEF treatments added nitrogen and potassium compared to the control.

Following Tables 6 and 7, results of the leaf tissue and soil analyses are discussed in regards to treatment effect and implications for WNO tree nutrient uptake. All nutrient values refer to the data found in Tables 6 and 7. All descriptions of values are in accordance with FGL standards. Soil descriptions include very low, moderately low, optimum, moderately high, and very high while leaf nutrient content descriptions usually consist of deficient, low, ample, high, and excessive.

Table 6. *Effects of Four Nutrition Treatments on Soil Properties. Fruit Growers Laboratory, Inc. (FGL) optimum ranges provided for reference. C stands for compost; VEF stands for vermicompost extract foliar; and LCC stands for legume cover cropping.*

Treatments	C+VEF	LCC+VEF	VEF	Control	FGL Optimum Ranges
Nutrient Values in Units of Pounds per Acre-Foot					
Nitrate-Nitrogen	96.4	41.6	19.6	23.2	40-80
Phosphorus P ₂ O ₅	651	64	55	64	140-280
Potassium-K ₂ O (Exch)	4,500	2,600	2,300	2,410	600-3,600
Potassium-K ₂ O (Sol)	218	75.4	66.7	65.2	94-470
Calcium (Exch)	18,800	1,700	18,500	18,600	15,000-20,000
Calcium (Sol)	374	147	169	159	160-640
Magnesium (Exch)	4,420	3,800	4,090	4,120	1,500-3,100
Magnesium (Sol)	226	89.9	105	95.3	73-220
Sodium (Exch)	1,280	1,120	1,160	1,180	0-1,400
Sodium (Sol)	956	693	748	700	0-740
Sulfate	359	174	207	173	120-3,800
Zinc	5.6	1.2	0.8	0.8	4-160
Manganese	28.4	17.2	18.8	19.2	6-240
Iron	21.6	16.4	18.8	20	40-200
Copper	2.4	2.4	2	2.4	1.2-41
Boron	3	1.48	1.32	1.32	1.2-8.4
Chloride	478	485	525	396	14-660
Soil Properties					
CEC (meq/100g)	36.3	31.6	34	34.2	14-35
pH	7.92	8.1	8.18	8.16	6-7.5
Soil Salinity (mmhos/cm)	1.69	1.12	1.22	1.10	0-2
SAR	4.8	5.6	5.6	5.4	0-6
Units in Percentages					
CEC-Calcium	64.50	67.10	67.90	67.80	60-80
CEC-Magnesium	25.10	24.70	24.80	24.80	10-20
CEC-Potassium	6.67	4.37	3.59	3.74	1-6
CEC-Sodium	3.83	3.86	3.71	3.74	0-5
Limestone	1.40	0.9	1.40	1.00	0-0.5
Moisture	12.20	7.40	6.50	7.20	3.4-24
Saturation	43.00	30.70	33.10	34.20	40-50
Organic Matter	3.76	1.23	1.39	1.43	

Table 7. *Effects of Four Nutrition Treatments on Leaf Tissue Analysis of Washington Navel Orange Trees. Fruit Growers Laboratory, Inc. (FGL) optimum ranges provided for reference. C stands for compost; VEF stands for vermicompost extract foliar; and LCC stands for legume cover cropping.*

Treatments	C+VEF	LCC+VEF	VEF	Control	FGL Optimum Ranges
Units in Percentages					
Leaf Macronutrient					
Total Nitrogen	2.60	2.48	2.33	1.89	2.60-2.80
Phosphorus	0.53	0.51	0.42	0.56	0.12-0.21
Potassium	1.38	1.64	1.54	1.21	0.70-3.30
Calcium	4.14	3.69	3.78	4.64	3.00-5.50
Magnesium	0.41	0.38	0.40	0.42	0.26-0.60
Sodium	0.22	0.15	0.23	0.12	0.00-0.16
Units in Parts Per Million					
Leaf Micronutrient					
Zinc	16.5	16.3	14.6	15	25-200
Manganese	19	22	22	22	25-300
Iron	44	43	45	46	60-200
Copper	12	11	10	11	5-40
Boron	160	134	143	182	31-300

Nutrients

Results of soil and leaf analysis are as follows.

Nitrate-Nitrogen

Nitrate-nitrogen soil levels of the control and VEF treatments were similarly low at 23.2 and 19.6 pounds per acre-foot respectively. This result is understandable since no amendment was applied to the soil under these treatments. The LCC+VEF treatment reported a nitrate-nitrogen level of 41.6 pounds per acre-foot, which is in the FGL optimum range. The increased nitrate-nitrogen level of the LCC treatment in comparison to the control and VEF treatments is a reflection of the nitrogen fixation capacity of the

leguminous cover crops planted in the treatment. The C+VEF treatment demonstrated the highest level of nitrate-nitrogen, 96.4 pounds per acre-foot, which is in the FGL moderately high range.

The FGL optimum range of leaf nitrogen is between 2.6% and 2.8%. The control had a deficient level at 1.9%. The VEF and LCC+VEF treatments had low leaf nitrogen at 2.33% and 2.48% respectively. The C+VEF treatment had a leaf nitrogen value inside the optimum range at 2.6%.

The 45 cubic feet of compost amendment applied to each WNO tree during the course of the experiment contained 3.5 pounds of total nitrogen, which partly explains the high quantity of nitrate-nitrogen in the C+VEF treatment soil and the increase in leaf tissue nitrogen percentage. The increased soil nitrate-nitrogen and organic matter will provide available nitrogen for WNO tree uptake into the future with limited loss to leaching, runoff, or denitrification. The enhancement of microbial life in the soil as a result of applied compost may have acted to mobilize soil nitrogen to some degree. Further soil and leaf sampling and testing is necessary for understanding the length of time this nutrient availability will continue.

Phosphorus

Phosphorus- P_2O_5 levels were similarly low in soil of the control, LCC, and VEF treatments at 64, 64, and 55 lbs/AF respectively. The phosphorus- P_2O_5 level in the soil of the C+VEF treatment was very high at 651 lbs/AF. All treatments had leaf phosphorus levels categorized as excessive by FGL standards. Fruit degreening was slow and incomplete which may be due to phosphorus toxicity. Phosphorus toxicity retards

degreening and accentuates regreening of fruit (Smith, 1966b). Citrus leaf phosphorus and nitrogen levels have an inverse effect on each other (Davies and Albrigo, 1998). Nitrogen added to the C+VEF and LCC+VEF treatment soils may be expected to reduce phosphorus leaf levels over time. Another sampling and testing of both soils and leaf tissue is required to fully understand the effects of the treatments on long-term phosphorus levels.

Potassium

Exchangeable potassium- K_2O levels in the soil of the control, VEF, and LCC+VEF were similar and optimum at 2,410, 2,300, and 2,600 lbs/AF respectively. Exchangeable nutrients are positively or negatively charged ions bound to soil particles by opposing charges. Nutrients in the soil solution are part of the aqueous liquid portion of the soil and are not bound to soil particles or other soluble materials. Exchangeable nutrients and nutrients in the soil solution are available for plant uptake although nutrients in solution are more readily available and exchangeable nutrients are in reserve. The exchangeable potassium level in the soil of the C+VEF treatment was moderately high at 4,550 lbs/AF. Potassium- K_2O in solution of the soils in the control, LCC+VEF, and VEF treatments was moderately low at 65.2, 75.4, and 66.7 lbs/AF, respectively. The C+VEF treatment had a level of K_2O in the soil solution of 218 lbs/AF, which is within the optimum range. All treatments had potassium leaf tissue levels inside the optimum range.

Calcium

Exchangeable calcium levels of all treatments were in the FGL optimum range. The exchangeable calcium level in the soil of the LCC+VEF treatment may have been slightly lower due to the calcium uptake by the cover crops and was not reincorporated back into the soil. The levels of calcium in solution in the soil of the LCC+VEF, VEF, and control treatments reported similar values at 147, 169, and 159 lbs/AF respectively. The C+VEF treatment had an amount of 374 lbs/AF of calcium in solution. The C+VEF treatment produced more than twice the amount of calcium in soil solution than any of the other treatments due to the fact that the compost amendment contained 46.6 lbs of calcium per ton. The microbial processes present in the compost may have increased the level of calcium in the soil solution. All treatments had calcium leaf tissue levels inside the optimum range.

Magnesium

The levels of exchangeable magnesium in the soils of the VEF and control treatments were similar at 4,090 and 4,120 lbs/AF respectively, whereas the LCC+VEF treatment had a slightly lower amount of exchangeable Mg at 3,800 lbs/AF. This may be due to cover crop uptake of the nutrient and the plant material was not reincorporated back into the soil by the time of soil sampling. The C+VEF treatment had a slightly higher amount of exchangeable Mg at 4,420 lbs/AF. The levels of Mg in solution of the soils in the LCC, VEF, and control treatments had similar amounts at 89.9, 105, and 95.3 lbs/AF, whereas the C+VEF treatment had an amount of 226 lbs/AF. All treatments had leaf magnesium levels inside the FGL standard optimum range.

Sodium

All four treatments had soil exchangeable sodium levels inside the FGL optimum range. The LCC+VEF and control treatments had similar values of sodium in solution inside the FGL optimum range for NWO production. The VEF treatment had a soil sodium in solution value slightly higher than the optimum range and the C+VEF treatment had a high level of sodium in solution.

The leaf sodium percentages of the control and LCC+VEF treatment were inside the FGL standard optimum range at 0.12% and 0.15% respectively. The VEF and C+VEF treatments had high leaf sodium values at 0.23% and 0.22% respectively. The high level of sodium in the vermicompost extract shown in the vermicompost extract analysis likely increased the level of sodium in the leaf tissue.

Sulfate

All treatments had soil sulfate levels inside the FGL optimum range. Sulfate was not tested in the leaf analysis.

Zinc

The zinc levels in the soils of the LCC+VEF, VEF, and control treatments had similar values at 1.2, 0.8, and 0.8 lbs/AF, respectively, and all are considered very low according to FGL. The C+VEF treatment boosted the amount of zinc in the soil to 5.6 lbs/AF, which is considered optimum by FGL. The LCC+VEF, VEF, and control treatment zinc values are considered very low according to FGL.

The leaf zinc levels of all treatments were below the optimum range. The VEF and control treatment zinc levels were categorized as deficient at 14.6 ppm and 15 ppm,

respectively. The LCC+VEF and C+VEF treatments were categorized as low at 16.3 ppm and 16.6 ppm, respectively, but both treatments still allow for greater uptake potential for WNO trees than the other two treatments.

Manganese

All treatments resulted in optimum levels of soil manganese. However, all treatments had leaf levels that were categorized as low.

Iron

The LCC+VEF, VEF, and control treatments had very low levels of soil iron as evaluated by FGL. The C+VEF treatment had a moderately low amount of soil iron. All treatments had levels of iron in the leaves that were categorized as low.

Copper

All treatments had optimum levels of copper in the soil as well as in the leaves.

Boron

All treatments also had optimum levels of boron in the soil as well as the leaves.

Chloride

Levels of chloride were inside the FGL optimum range for all treatments.

Chloride levels were not tested in the leaves.

Soil Properties

All treatments had soil pH values categorized as moderately alkaline by FGL standards. The C+VEF treatment reported the lowest pH value at 7.92 and the

LCC+VEF, VEF, and control treatments had soil pH values of 8.10, 8.18, and 8.16, respectively.

The soil salinity levels of the treatments were similar and were categorized as satisfactory by FGL. The animal manures used in the compost may have slightly increased the soil salinity of the C+VEF treatment.

The sodium absorption ratio (SAR) values of the LCC+VEF, VEF, and control treatments were similar at 5.6, 5.6, and 5.4 respectively. The C+VEF treatment had a slightly lower SAR value at 4.8. All treatment SAR values were categorized as satisfactory by FGL. The slightly lower SAR level of C+VEF treatment reflects the greater amounts of added calcium and magnesium to the soil solution in relation to sodium.

The limestone percentages in the treatment soils were 0.9% and 1% in the LCC+VEF and control treatments, respectively, and 1.4% in both the C+VEF and VEF treatments. All treatments had high soil limestone percentages categorized as a possible problem by FGL standards. No lime inputs were required. The high limestone percentages of the treatment soils directly reflect the prominence of limestone in the soil parent material.

The soil moisture percentages of the treatments all were in the optimum range for WNO production according to FGL standards. Moisture percentage is a measurement of the soil sample weight as received and after drying to determine the percentage of water content in the soil. The higher soil moisture percentage of the C+VEF treatment made more water available for WNO tree uptake during hot, arid conditions of summer and early fall.

The soil water saturation percentages of the treatments are low according to FGL standards in the LCC+VEF, VEF, and control treatments and optimum in the C+VEF treatment. The soil saturation percentage is a measurement of the dry weight of the sample and the amount of water necessary for complete saturation of soil pores, and reflects soil texture, which affects water holding capacity. The greater water saturation percentage of the soil in the C+VEF treatment allowed WNO trees more capacity for water uptake.

The percentage of soil organic matter in the LCC+VEF, VEF, and control treatments had similar values at 1.28, 1.39, and 1.43 respectively. The slightly lower value of the LCC+VEF treatment reflects the organic matter consumed by soil microbes as the fixed nitrogen on the root nodules of the leguminous cover crop breaks down. The cover crops were incorporated minimally with a shovel and hoe so as not to disturb the roots of the trees. Thus, most of the above ground plant material was effectively a mulch so it likely did not contribute to soil organic matter. The C+VEF treatment had the highest organic matter percentage at 3.76%.

The nitrogen to potassium ratios in the leaves of the treatments was 1.5 for the LCC+VEF, VEF, and control treatments, and 1.9 in the C+VEF treatment (Table 7). The optimum range of N:K ratios is 1.6 to 2.2 with nitrogen percentage greater than 1.8% and potassium greater than 0.9% (Davies and Albrigo, 1998). All treatments had nitrogen and potassium percentages above 1.8% and 0.9%, respectively.

Fruit Yield and Fruit Nutrient Content

There were significant differences in fruit yield among treatments. The C+VEF treatment had a significantly greater fruit yield (Figure 1; Appendix B, page 75) and number of fruit per treatment (Figure 2; Appendix B, page 77) than the other treatments. There were no significant differences in fruit yield and number among the LCC+VEF, VEF, and control treatments. No significant difference was found in fruit size among all four treatments (Figure 3; Appendix B, page 79).

Fig. 1. Effect of Four Nutrient Treatments on Washington Navel Orange Yield. The boxplot graph shows sample minimum, lower quartile, median, upper quartile, and sample maximum. The x-axis treatments are: CON (control), C+VEF (compost and vermicompost extract foliar applications), LCC+VEF (legume cover cropping and vermicompost extract foliar applications), and VEF (vermicompost extract foliar applications).

Fig. 2. Effect of Four Nutrient Treatments on Washington Navel Orange Yield. The boxplot graph shows sample minimum, lower quartile, median, upper quartile, and sample maximum. The x-axis treatments are: CON (control), C+VEF (compost and vermicompost extract foliar applications), LCC+VEF (legume cover cropping and vermicompost extract foliar applications), and VEF (vermicompost extract foliar applications).

The results of measurements taken on tree height (Figure 4; Appendix B, page 80) and circumference (Figure 5; Appendix B, page 80) indicated no significant difference among treatments. These measurements were taken to isolate WNO fruit yield from tree size.

The effect of the four nutrition treatments on fruit yield, expressed this time as pounds per tree, were compared with nutrient output (nutrient removal due to yield), which was calculated from the data (Table 8). Nutrient output results were based upon a compromised sampling due to confiscation. The C+VEF treatment apparently had a greater removal of nutrients as a result of yield than the other treatments, but statistical

analysis was not conducted. The overall production performance of the C+VEF treatment may have been enhanced due to the added nitrogen and potassium made available for uptake by the compost during phase 1 and 2 of fruit development.

Fig. 3. Effect of Four Nutrient Treatments on Fruit Size of Washington Navel Orange. The boxplot graph shows sample minimum, lower quartile, median, upper quartile, and sample maximum. The x-axis treatments are: CON (control), C+VEF (compost and vermicompost extract foliar applications), LCC+VEF (legume cover cropping and vermicompost extract foliar applications), and VEF (vermicompost extract foliar applications).

Fig. 4. Height of Washington Navel Orange Trees Per Treatment, Measured at Harvest. The boxplot graph shows sample minimum, lower quartile, median, upper quartile, and sample maximum. The x-axis treatments are: CON (control), C+VEF (compost and vermicompost extract foliar applications), LCC+VEF (legume cover cropping and vermicompost extract foliar applications), and VEF (vermicompost extract foliar applications).

Fig. 5. Circumference of Washington Navel Orange Trees Per Treatment, Measured at Harvest. The boxplot graph shows sample minimum, lower quartile, median, upper quartile, and sample maximum. The x-axis treatments are: CON (control), C+VEF (compost and vermicompost extract foliar applications), LCC+VEF (legume cover cropping and vermicompost extract foliar applications), and VEF (vermicompost extract foliar applications).

Table 8. *Effect of Four Nutrition Treatments on Mean Fruit Yield and Mean Nutrient Output of Washington Navel Orange Trees. Average of Each Treatment. C stands for compost; VEF stands for vermicompost extract foliar; and LCC stands for legume cover cropping.*

Treatments	C+VEF	LCC+VEF	VEF	Control
Units in Pounds Per Tree				
Fruit Yield	28.3	7.3	5.6	8.48
Nutrient Output				
Nitrogen	0.094	0.013	0.011	0.025
Phosphorus	0.095	0.0025	0.0048	0.0061
Potassium	0.122	0.02	0.026	0.033
Calcium	0.056	0.015	0.009	0.011
Magnesium	0.012	0.0018	0.0025	0.003
Sodium	0.0023	0.00075	0.00028	0.00048
Boron	0.00033	0.000063	0.000057	0.000072
Copper	0.0009	0.000037	0.000038	0.000048
Iron	0.00078	0.000075	0.000052	0.000061
Manganese	0.00056	0.000012	0.0000093	0.000012

In terms of the performance of the different treatments to compensate for nutrient removal due to fruit harvest, the C+VEF treatment added the most nutrients to the soil and improved soil qualities for WNO tree uptake of nutrients for future crops more than the other treatments (Table 6). The LCC+VEF treatment doubled the amount of soil nitrate-nitrogen of that in the control treatment, but organic matter and CEC decreased.

The VEF treatment added leaf nitrogen for tree growth and increased sodium levels to the high range. Further research is needed to develop a vermicompost extract for WNO leaf surfaces that would lower sodium levels and increase other nutrients.

Further research is needed to fully understand the potential of mineralized nutrients realized by increased microbial activity in the soil stimulated as a result of compost applications. Humic acid levels of compost may aid in nutrient uptake and testing humic acid in the treatment soils may provide a better understanding of the contribution of compost applications on WNO tree nutrient uptake (Canellas et al., 2002).

The percentage of total soluble solids (TSS) of all treatments exceeded the 10% to 20% range for fresh fruit stated by (Davies and Albrigo, 1998) to be indicative of high quality. The TSS percentages of the treatments showed C+VEF 28%, LCC+VEF 21.9%, VEF 24.6% and the control 25.1%. Fruit TSS contains carbohydrates, organic acids, proteins, fats and various minerals (Davies and Albrigo, 1998).

CHAPTER 5

Conclusions and Recommendations

The optimum levels of all nutrients are required for WNO trees to produce maximum yields. The experiment showed that compost applications can supply sufficient nutrients to increase yields for WNO trees. Legume cover crops did not supply nutrients required to increase yield during the experiment but did increase soil and leaf nitrogen content. Vermicompost extract also did not increase yield but did increase leaf nitrogen content. All the treatments have their merit and can be effective nutrient contributors to WNO production with the correct application.

Compost applications were proven to increase WNO fruit yield, soil and leaf nutrient content, and enhance soil properties that could improve nutrient uptake for future crops. The increases in soil organic matter, soil moisture, and saturation as a result of the compost applications will provide a substantial amount of available water and nutrients for WNO trees in the hot, dry summer and early-fall season when the orchard is irrigated once every three weeks. Another sampling of the soil and leaves in 2012 would help determine the amount of nutrient uptake by the WNO trees as a result of the compost applications and the rate of nutrient dispersion in the soil. This information could be used to monitor nutrient levels. If the nutrient levels remain the same or increase then the compost application rate could be reduced to once every 6 months or a year to maintain optimum levels. It is important to apply compost frequently at first to establish optimum nutrient content and improve soil properties and then reduce application rates to maintain optimum levels. Testing the soil microbial activity and humic acid levels could further

the understanding of nutrient availability for WNO tree uptake as a result of the applied compost.

The legume cover crop was not incorporated into the soil sufficiently enough to increase soil nutrient levels, except for nitrogen, or soil organic matter, thus fruit yield did not increase. The added nitrogen provided by root nodules of the nitrogen-fixing crops may have been responsible for increased nitrogen content in the leaves and the decrease in organic matter. A more thorough incorporation of the cover crops would have been a great disturbance to the shallow roots of the WNO trees. Planting the cover crop in the orchard alleys would allow space for proper incorporation into the soil and thus the potential benefits of the cover crop as green manure could be realized. The current management uses the orchard alleys for livestock feed and periodically lets the alleys go fallow. The cover crop cultivars used in the experiment are traditionally planted and harvested as a food crop and field residues are used for livestock feed. Incorporating these residues into the soil would increase soil nutrient content and improve soil properties.

Vermicompost extract foliar applications did provide WNO trees with increased leaf nitrogen content compared to the control, but did not provide enough nutrients to increase yield. Vermicompost extract could be most effective applied twice a week during phase 1 of WNO fruit development when nutrient requirement for fruit development is at its peak. The quality of the extract could be improved by aeration and by using finished compost to feed the worms. Further experimentation with extract quality and timing of foliar applications on WNO trees is required to determine the potential benefits.

A great diversity of microorganisms are ingested and distributed by worms throughout the soil environment. This includes both human pathogens and plant pathogens. Prior to vermicomposting, manures should be composted for a sufficient amount of time and at a sufficiently high temperature in order to eliminate these pathogenic microorganisms.

All nutrient enhancing strategies employed in the experiment were constructed onsite from materials derived onsite. The livestock manures and carbon materials used in the compost translated into increased yield in WNO trees with labor being the only farm expenditure. The cycling of nutrients inside a small, diversified farming system could increase productivity and improve efficiency of the farm as a whole.

In summary, the following recommendations stem from this research:

- 1) Another sampling of soil and leaves in 2012;
- 2) Compost application rates could be reduced to every six months or a year;
- 3) Testing the soil microbial activity and humic acid levels;
- 4) Planting the cover crop in orchard alleys; and
- 5) Further experimentation with vermicompost extract quality and timing of foliar applications.

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Appendices

- A. Fruit Growers Laboratory, Inc. Soil, Leaf, Water, and Amendment Analysis Results
- B. Statistical Analysis of Fruit Yield and Tree Size
- C. Photo Essay of the Experiment

APPENDIX A

Fruit Growers Laboratory, Inc. Soil, Leaf, Water, and Amendment Analysis Results

FRUIT GROWERS LABORATORY, INC.

Analytical Chemists
www.fglinc.com

June 27, 2011
Patty Frazer
102 Ravenhill Road
Orinda, CA 94563

Lab ID : SP 1105923-002
Customer ID : 2-23787

Sampled On : May 23, 2011
Sampled By : Payton Carling
Received On : June 13, 2011
Depth : N/A
Meth Irrg. :

Description : GMCC+VTF
Project : Payton Carling/Cal Poly Thesis

WASHINGTON SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation					
Primary Nutrients				Very Low	Moderately Low	Optimum	Moderately High	Very High	
	Nitrate-Nitrogen	41.6	Lbs/AF	40 - 80	<div><div></div></div>				
	Phosphorus-P ₂ O ₅	64	Lbs/AF	140 - 280	<div><div></div></div>				
	Potassium-K ₂ O (Exch)	2600	Lbs/AF	600 - 3600	<div><div></div></div>				
	Potassium-K ₂ O (Sol)	75.4	Lbs/AF	94 - 470	<div><div></div>3%</div>				
Secondary Nutrients									
	Calcium (Exch)	17000	Lbs/AF	15000 - 20000	<div><div></div></div>				
	Calcium (Sol)	147	Lbs/AF	160 - 640	<div><div></div>16%</div>				
	Magnesium (Exch)	3800	Lbs/AF	1500 - 3100	<div><div></div></div>				
	Magnesium (Sol)	89.9	Lbs/AF	73 - 220	<div><div></div>16%</div>				
	Sodium (Exch)	1120	Lbs/AF	0.0 - 1400	<div><div></div></div>				
	Sodium (Sol)	693	Lbs/AF	0.0 - 740	<div><div></div>5%</div>				
	Sulfate	174	Lbs/AF	120 - 3800	<div><div></div></div>				
Micro Nutrients									
	Zinc	1.20	Lbs/AF	4.0 - 160	<div><div></div></div>				
	Manganese	17.2	Lbs/AF	6.0 - 240	<div><div></div></div>				
	Iron	16.4	Lbs/AF	40 - 200	<div><div></div></div>				
	Copper	2.40	Lbs/AF	1.2 - 41	<div><div></div></div>				
	Boron	1.48	Lbs/AF	1.2 - 8.4	<div><div></div></div>				
	Chloride	485	Lbs/AF	14 - 660	<div><div></div></div>				
CEC	31.6	meq/100g	14 - 35	<div><div></div></div>					
% Base Saturation									
CEC - Calcium	67.1	%	60 - 80	<div><div></div></div>					
CEC - Magnesium	24.7	%	10 - 20	<div><div></div></div>					
CEC - Potassium	4.37	%	1.0 - 6.0	<div><div></div></div>					
CEC - Sodium	3.86	%	0.0 - 5.0	<div><div></div></div>					
CEC - Hydrogen	0.00	%	0.0 - 3.0	<div><div></div></div>					
				Strongly Acidic	Moderately Acidic	Near Neutral	Moderately Alkaline	Strongly Alkaline	
pH	8.10	---	6.0 - 7.5	<div><div></div></div>					

Good Problem Indicates physical conditions and/or phenological and amendment requirements.
Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

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June 27, 2011

Patty Frazer

Lab ID : SP 1105923-002

Customer ID : 2-23787

Description : GMCC + VTF

WASHINGTON SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation							
Others				Satisfactory	Possible Problem	Moderate Problem	Increasing Problem				
Soil Salinity	1.12	mmhos/cm	0.0 - 2.0								
SAR	5.6		0.0 - 6.0								
Limestone	0.9	%	0.0 - 0.50								
				0	1	2	3	4	5	6	
Lime Requirement	0	Tons/AF	---								
				Very Low	Moderately Low	Optimum	Moderately High	Very High			
Moisture	7.4	%	3.1 - 22								
				Loamy Sand	Sandy Loam	Loam	Silt Loam	Clay Loam	Clay	Organic	
Saturation	30.7	%	40 - 50								

Good Problem Indicates physical conditions and/or phenological and amendment requirements.
 Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

- 1) The need for soil Nitrate is dependant upon crop phenology (Growth Stage) and crop requirement. A soil Nitrate level of 10 - 40 ppm is preferred for a short time during critical periods of uptake into the tree. It is highly desirable to have low soil Nitrate (< 5ppm) prior to winter rainfall and cold soil conditions. Use the leaf Nitrogen level to determine primary Nitrogen requirement.
- 2) Trifoliolate & Citrumelo rootstocks are very sensitive to limestone and should not be planted in soils containing limestone. Other rootstock are moderately sensitive to limestone. Ascertain the rootstock tolerance prior to planting.

FRUIT GROWERS LABORATORY, INC.

Chad Lessard, Director of Ag. Services

CEL:JRJ

FRUIT GROWERS LABORATORY, INC.

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June 27, 2011

Patty Frazer

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Customer ID : 2-23787

Sampled On : May 23, 2011

Sampled By : Payton Carling

Received On : June 13, 2011

Depth : N/A

Meth Irrg. :

Description : VTF

Project : Payton Carling/Cal Poly Thesis

WASHINGTON SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation				
				Very Low	Moderately Low	Optimum	Moderately High	Very High
Primary Nutrients								
Nitrate-Nitrogen	19.6	Lbs/AF	40 - 80					
Phosphorus-P ₂ O ₅	55	Lbs/AF	140 - 280					
Potassium-K ₂ O (Exch)	2300	Lbs/AF	640 - 3800					
Potassium-K ₂ O (Sol)	66.7	Lbs/AF	94 - 470					
Secondary Nutrients								
Calcium (Exch)	18500	Lbs/AF	16000 - 22000					
Calcium (Sol)	169	Lbs/AF	160 - 640					
Magnesium (Exch)	4090	Lbs/AF	1600 - 3300					
Magnesium (Sol)	105	Lbs/AF	73 - 220					
Sodium (Exch)	1160	Lbs/AF	0.0 - 1600					
Sodium (Sol)	748	Lbs/AF	0.0 - 800					
Sulfate	207	Lbs/AF	120 - 3800					
Micro Nutrients								
Zinc	0.800	Lbs/AF	4.0 - 160					
Manganese	18.8	Lbs/AF	6.0 - 240					
Iron	18.8	Lbs/AF	40 - 200					
Copper	2.00	Lbs/AF	1.2 - 41					
Boron	1.32	Lbs/AF	1.2 - 8.4					
Chloride	525	Lbs/AF	14 - 660					
CEC	34.0	meq/100g	14 - 35					
% Base Saturation								
CEC - Calcium	67.9	%	60 - 80					
CEC - Magnesium	24.8	%	10 - 20					
CEC - Potassium	3.59	%	1.0 - 6.0					
CEC - Sodium	3.71	%	0.0 - 5.0					
CEC - Hydrogen	0.00	%	0.0 - 3.0					
				Strongly Acidic	Moderately Acidic	Near Neutral	Moderately Alkaline	Strongly Alkaline
pH	8.18	---	6.0 - 7.5					

Good Problem Indicates physical conditions and/or phenological and amendment requirements.

Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

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June 27, 2011

Patty Frazer

Lab ID : SP 1105923-003

Customer ID : 2-23787

Description : VTF

WASHINGTON SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation									
Others				Satisfactory		Possible Problem		Moderate Problem		Increasing Problem			
	Soil Salinity	1.22	mmhos/cm	0.0 - 2.0	<div></div>								
	SAR	5.6		0.0 - 6.0	<div></div>								
	Limestone	1.4	%	0.0 - 0.50	<div></div>								
				0	1	2	3	4	5	6			
Lime Requirement	0	Tons/AF	---	<div></div>									
				Very Low	Moderately Low		Optimum		Moderately High		Very High		
Moisture	6.5	%	3.3 - 23	<div></div>									
				Loamy Sand	Sandy Loam	Loam	Silt Loam	Clay Loam	Clay	Organic			
Saturation	33.1	%	40 - 50	<div></div>									

Good Problem Indicates physical conditions and/or phenological and amendment requirements.

Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

- 1) The need for soil Nitrate is dependant upon crop phenology (Growth Stage) and crop requirement. A soil Nitrate level of 10 - 40 ppm is preferred for a short time during critical periods of uptake into the tree. It is highly desirable to have low soil Nitrate (< 5ppm) prior to winter rainfall and cold soil conditions. Use the leaf Nitrogen level to determine primary Nitrogen requirement.
- 2) Trifoliolate & Citrumelo rootstocks are very sensitive to limestone and should not be planted in soils containing limestone. Other rootstock are moderately sensitive to limestone. Ascertain the rootstock tolerance prior to planting.

FRUIT GROWERS LABORATORY, INC.

Chad Lessard, Director of Ag. Services

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June 27, 2011

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102 Ravenhill Road
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Lab ID : SP 1105923-004

Customer ID : 2-23787

Sampled On : May 23, 2011

Sampled By : Payton Carling

Received On : June 13, 2011

Depth : N/A

Meth Irrg. :

Description : Control

Project : Payton Carling/Cal Poly Thesis

WASHINGTON SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation				
				Very Low	Moderately Low	Optimum	Moderately High	Very High
Primary Nutrients								
Nitrate-Nitrogen	23.2	Lbs/AF	40 - 80	<div></div>				
Phosphorus-P ₂ O ₅	64	Lbs/AF	140 - 280	<div></div>				
Potassium-K ₂ O (Exch)	2410	Lbs/AF	640 - 3900	<div></div>				
Potassium-K ₂ O (Sol)	65.2	Lbs/AF	94 - 470	<div></div> 3%				
Secondary Nutrients								
Calcium (Exch)	18600	Lbs/AF	16000 - 22000	<div></div>				
Calcium (Sol)	159	Lbs/AF	160 - 640	<div></div> 17%				
Magnesium (Exch)	4120	Lbs/AF	1700 - 3300	<div></div>				
Magnesium (Sol)	95.3	Lbs/AF	73 - 220	<div></div> 16%				
Sodium (Exch)	1180	Lbs/AF	0.0 - 1600	<div></div>				
Sodium (Sol)	700	Lbs/AF	0.0 - 780	<div></div> 64%				
Sulfate	173	Lbs/AF	120 - 3800	<div></div>				
Micro Nutrients								
Zinc	0.800	Lbs/AF	4.0 - 160	<div></div>				
Manganese	19.2	Lbs/AF	6.0 - 240	<div></div>				
Iron	20.0	Lbs/AF	40 - 200	<div></div>				
Copper	2.40	Lbs/AF	1.2 - 41	<div></div>				
Boron	1.32	Lbs/AF	1.2 - 8.4	<div></div>				
Chloride	396	Lbs/AF	14 - 660	<div></div>				
CEC	34.2	meq/100g	14 - 35	<div></div>				
% Base Saturation								
CEC - Calcium	67.8	%	60 - 80	<div></div>				
CEC - Magnesium	24.8	%	10 - 20	<div></div>				
CEC - Potassium	3.74	%	1.0 - 6.0	<div></div>				
CEC - Sodium	3.74	%	0.0 - 5.0	<div></div>				
CEC - Hydrogen	0.00	%	0.0 - 3.0	<div></div>				
				Strongly Acidic	Moderately Acidic	Near Neutral	Moderately Alkaline	Strongly Alkaline
pH	8.16	---	6.0 - 7.5	<div></div>				

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June 27, 2011

Patty Frazer

Lab ID : SP 1105923-004

Customer ID : 2-23787

Description : Control

WASHINGTON SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation							
Others				Satisfactory	Possible Problem	Moderate Problem	Increasing Problem				
Soil Salinity	1.10	mmhos/cm	0.0 - 2.0								
SAR	5.4		0.0 - 6.0								
Limestone	1.0	%	0.0 - 0.50								
				0	1	2	3	4	5	6	
Lime Requirement	0	Tons/AF	---								
				Very Low	Moderately Low	Optimum	Moderately High	Very High			
Moisture	7.2	%	3.4 - 24								
				Loamy Sand	Sandy Loam	Loam	Silt Loam	Clay Loam	Clay	Organic	
Saturation	34.2	%	40 - 50								

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- 2) Trifoliolate & Citrumelo rootstocks are very sensitive to limestone and should not be planted in soils containing limestone. Other rootstock are moderately sensitive to limestone. Ascertain the rootstock tolerance prior to planting.

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Lab ID : SP 1105923-007

Customer ID : 2-23787

Sampled On : May 23, 2011

Sampled By : Payton Carling

Received On : June 13, 2011

Depth : N/A

Meth Irrg. :

Description : Hurricane Effected Orchard

Project : Payton Carling/Cal Poly Thesis

WASHINGTON SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation				
				Very Low	Moderately Low	Optimum	Moderately High	Very High
Primary Nutrients								
Nitrate-Nitrogen	32.4	Lbs/AF	40 - 80	<div><div></div></div>				
Phosphorus-P ₂ O ₅	55	Lbs/AF	140 - 280	<div><div></div></div>				
Potassium-K ₂ O (Exch)	3670	Lbs/AF	1000 - 6300	<div><div></div></div>				
Potassium-K ₂ O (Sol)	40.5	Lbs/AF	94 - 470	<div><div></div>1%</div>				
Secondary Nutrients								
Calcium (Exch)	26100	Lbs/AF	27000 - 36000	<div><div></div></div>				
Calcium (Sol)	156	Lbs/AF	160 - 640	<div><div></div>11%</div>				
Magnesium (Exch)	7870	Lbs/AF	2700 - 5400	<div><div></div></div>				
Magnesium (Sol)	114	Lbs/AF	73 - 220	<div><div></div>13%</div>				
Sodium (Exch)	4880	Lbs/AF	0.0 - 2600	<div><div></div></div>				
Sodium (Sol)	1280	Lbs/AF	0.0 - 810	<div><div></div>76%</div>				
Sulfate	507	Lbs/AF	120 - 3800	<div><div></div></div>				
Micro Nutrients								
Zinc	1.20	Lbs/AF	4.0 - 160	<div><div></div></div>				
Manganese	18.0	Lbs/AF	6.0 - 240	<div><div></div></div>				
Iron	39.6	Lbs/AF	40 - 200	<div><div></div></div>				
Copper	3.60	Lbs/AF	1.2 - 41	<div><div></div></div>				
Boron	4.24	Lbs/AF	1.2 - 8.4	<div><div></div></div>				
Chloride	1080	Lbs/AF	14 - 660	<div><div></div></div>				
CEC	56.0	meq/100g	14 - 35	<div><div></div></div>				
% Base Saturation								
CEC - Calcium	58.0	%	60 - 80	<div><div></div></div>				
CEC - Magnesium	28.9	%	10 - 20	<div><div></div></div>				
CEC - Potassium	3.48	%	1.0 - 6.0	<div><div></div></div>				
CEC - Sodium	9.48	%	0.0 - 5.0	<div><div></div></div>				
CEC - Hydrogen	0.00	%	0.0 - 3.0	<div><div></div></div>				
				Strongly Acidic	Moderately Acidic	Near Neutral	Moderately Alkaline	Strongly Alkaline
pH	8.34	---	6.0 - 7.5	<div><div></div></div>				

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June 27, 2011

Patty Frazer

Lab ID : SP 1105923-007

Customer ID : 2-23787

Description : Hurricane Effected Orchard

WASHINGTON SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation									
Others				Satisfactory		Possible Problem		Moderate Problem		Increasing Problem			
	Soil Salinity	1.87	mmhos/cm	0.0 - 2.0	<div></div>								
	SAR	9.5		0.0 - 6.0	<div></div>		<div></div>		<div></div>				
	Limestone	2.1	%	0.0 - 0.50	<div></div>								
				0	1	2	3	4	5	6			
Lime Requirement	0	Tons/AF	---	<div></div>									
				Very Low	Moderately Low		Optimum		Moderately High		Very High		
Moisture	4.2	%	3.5 - 25	<div></div>									
				Loamy Sand	Sandy Loam	Loam	Silt Loam	Clay Loam	Clay	Organic			
Saturation	35.2	%	40 - 50	<div></div>									

Good Problem Indicates physical conditions and/or phenological and amendment requirements.

Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

- 1) The need for soil Nitrate is dependant upon crop phenology (Growth Stage) and crop requirement. A soil Nitrate level of 10 - 40 ppm is preferred for a short time during critical periods of uptake into the tree. It is highly desirable to have low soil Nitrate (< 5ppm) prior to winter rainfall and cold soil conditions. Use the leaf Nitrogen level to determine primary Nitrogen requirement.
- 2) Trifoliolate & Citrumelo rootstocks are very sensitive to limestone and should not be planted in soils containing limestone. Other rootstock are moderately sensitive to limestone. Ascertain the rootstock tolerance prior to planting.

FRUIT GROWERS LABORATORY, INC.

Chad Lessard, Director of Ag. Services

CEL:JRJ

FRUIT GROWERS LABORATORY, INC.

Analytical Chemists
www.fglinc.com

July 12, 2011

Patty Frazer

102 Ravenhill Road
Orinda, CA 94563

Lab ID : SP 1105923-001

Customer ID : 2-23787

Sampled On : May 23, 2011

Sampled By : Payton Carling

Received On : June 13, 2011

Depth : N/A

Meth Irrg. :

Description : C+VTF

Project : Payton Carling/Cal Poly Thesis

WASHINGTON SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation				
				Very Low	Moderately Low	Optimum	Moderately High	Very High
Primary Nutrients								
Nitrate-Nitrogen	96.4	Lbs/AF	40 - 80					
Phosphorus-P ₂ O ₅	651	Lbs/AF	140 - 280					
Potassium-K ₂ O (Exch)	4550	Lbs/AF	680 - 4100					
Potassium-K ₂ O (Sol)	218	Lbs/AF	94 - 470					
Secondary Nutrients								
Calcium (Exch)	18800	Lbs/AF	18000 - 23000					
Calcium (Sol)	374	Lbs/AF	160 - 640					
Magnesium (Exch)	4420	Lbs/AF	1800 - 3500					
Magnesium (Sol)	226	Lbs/AF	73 - 220					
Sodium (Exch)	1280	Lbs/AF	0.0 - 1700					
Sodium (Sol)	956	Lbs/AF	0.0 - 1200					
Sulfate	359	Lbs/AF	120 - 3800					
Micro Nutrients								
Zinc	5.60	Lbs/AF	4.0 - 160					
Manganese	28.4	Lbs/AF	6.0 - 240					
Iron	21.6	Lbs/AF	40 - 200					
Copper	2.40	Lbs/AF	1.2 - 41					
Boron	3.00	Lbs/AF	1.2 - 8.4					
Chloride	478	Lbs/AF	14 - 660					
CEC	36.3	meq/100g	14 - 35					
% Base Saturation								
CEC - Calcium	64.5	%	60 - 80					
CEC - Magnesium	25.1	%	10 - 20					
CEC - Potassium	6.67	%	1.0 - 6.0					
CEC - Sodium	3.83	%	0.0 - 5.0					
CEC - Hydrogen	0.00	%	0.0 - 3.0					
pH				Strongly Acidic	Moderately Acidic	Near Neutral	Moderately Alkaline	Strongly Alkaline
pH	7.92	---	6.0 - 7.5					

Good Problem Indicates physical conditions and/or phenological and amendment requirements.

Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

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July 12, 2011

Patty Frazer

Lab ID : SP 1105923-001

Customer ID : 2-23787

Description : C+VTF

WASHINGTON SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation									
Others				Satisfactory		Possible Problem		Moderate Problem		Increasing Problem			
Soil Salinity	1.69	mmhos/cm	0.0 - 2.0	<div></div>									
SAR	4.8		0.0 - 6.0	<div></div>									
Limestone	1.4	%	0.0 - 0.50	<div></div>									
				0	1	2	3	4	5	6			
Lime Requirement	0	Tons/AF	---	<div></div>									
				Very Low		Moderately Low		Optimum		Moderately High			
Moisture	12.2	%	4.3 - 30	<div></div>									
				Loamy Sand	Sandy Loam	Loam	Silt Loam	Clay Loam	Clay	Organic			
Saturation	43.0	%	40 - 50	<div></div>									
% Organic Matter	3.76	%	---	Mineral				Organic					
				<div></div>									

Good Problem Indicates physical conditions and/or phenological and amendment requirements.

Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

1) The need for soil Nitrate is dependant upon crop phenology (Growth Stage) and crop requirement. A soil Nitrate level of 10 - 40 ppm is preferred for a short time during critical periods of uptake into the tree. It is highly desirable to have low soil Nitrate (< 5ppm) prior to winter rainfall and cold soil conditions. Use the leaf Nitrogen level to determine primary Nitrogen requirement.

2) Trifoliolate & Citrumelo rootstocks are very sensitive to limestone and should not be planted in soils containing limestone. Other rootstock are moderately sensitive to limestone. Ascertain the rootstock tolerance prior to planting.

FRUIT GROWERS LABORATORY, INC.

CEL:JRJ

Chad Lessard, Director of Ag. Services

FRUIT GROWERS LABORATORY, INC.

Analytical Chemists
www.fglinc.com

July 12, 2011

Patty Frazer

102 Ravenhill Road
Orinda, CA 94563

Lab ID : SP 1105923-002

Customer ID : 2-23787

Sampled On : May 23, 2011

Sampled By : Payton Carling

Received On : June 13, 2011

Depth : N/A

Meth Irrg. :

Description : GMCC+VTF

Project : Payton Carling/Cal Poly Thesis

WASHINGTON SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation				
				Very Low	Moderately Low	Optimum	Moderately High	Very High
Primary Nutrients								
Nitrate-Nitrogen	41.6	Lbs/AF	40 - 80	<div></div>				
Phosphorus-P ₂ O ₅	64	Lbs/AF	140 - 280	<div></div>				
Potassium-K ₂ O (Exch)	2600	Lbs/AF	600 - 3600	<div></div>				
Potassium-K ₂ O (Sol)	75.4	Lbs/AF	94 - 470	<div></div> 3%				
Secondary Nutrients								
Calcium (Exch)	17000	Lbs/AF	15000 - 20000	<div></div>				
Calcium (Sol)	147	Lbs/AF	160 - 640	<div></div> 16%				
Magnesium (Exch)	3800	Lbs/AF	1500 - 3100	<div></div>				
Magnesium (Sol)	89.9	Lbs/AF	73 - 220	<div></div> 16%				
Sodium (Exch)	1120	Lbs/AF	0.0 - 1400	<div></div>				
Sodium (Sol)	693	Lbs/AF	0.0 - 740	<div></div> 5%				
Sulfate	174	Lbs/AF	120 - 3800	<div></div>				
Micro Nutrients								
Zinc	1.20	Lbs/AF	4.0 - 160	<div></div>				
Manganese	17.2	Lbs/AF	6.0 - 240	<div></div>				
Iron	16.4	Lbs/AF	40 - 200	<div></div>				
Copper	2.40	Lbs/AF	1.2 - 41	<div></div>				
Boron	1.48	Lbs/AF	1.2 - 8.4	<div></div>				
Chloride	485	Lbs/AF	14 - 660	<div></div>				
CEC	31.6	meq/100g	14 - 35	<div></div>				
% Base Saturation								
CEC - Calcium	67.1	%	60 - 80	<div></div>				
CEC - Magnesium	24.7	%	10 - 20	<div></div>				
CEC - Potassium	4.37	%	1.0 - 6.0	<div></div>				
CEC - Sodium	3.86	%	0.0 - 5.0	<div></div>				
CEC - Hydrogen	0.00	%	0.0 - 3.0	<div></div>				
				Strongly Acidic	Moderately Acidic	Near Neutral	Moderately Alkaline	Strongly Alkaline
pH	8.10	---	6.0 - 7.5	<div></div>				

Good Problem Indicates physical conditions and/or phenological and amendment requirements.

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July 12, 2011

Patty Frazer

Lab ID : SP 1105923-002

Customer ID : 2-23787

Description : GMCC + VTF

WASHINGTON SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation									
Others				Satisfactory		Possible Problem		Moderate Problem		Increasing Problem			
Soil Salinity	1.12	mmhos/cm	0.0 - 2.0	<div><div></div></div>									
SAR	5.6		0.0 - 6.0	<div><div></div></div>									
Limestone	0.9	%	0.0 - 0.50	<div><div></div></div>									
				0	1	2	3	4	5	6			
Lime Requirement	0	Tons/AF	---	<div><div></div></div>									
				Very Low		Moderately Low		Optimum		Moderately High			
Moisture	7.4	%	3.1 - 22	<div><div></div></div>									
				Loamy Sand	Sandy Loam	Loam	Silt Loam	Clay Loam	Clay	Organic			
Saturation	30.7	%	40 - 50	<div><div></div></div>									
				Mineral				Organic					
% Organic Matter	1.23	%	---	<div><div></div></div>									

Good Problem Indicates physical conditions and/or phenological and amendment requirements.

Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

1) The need for soil Nitrate is dependant upon crop phenology (Growth Stage) and crop requirement. A soil Nitrate level of 10 - 40 ppm is preferred for a short time during critical periods of uptake into the tree. It is highly desirable to have low soil Nitrate (< 5ppm) prior to winter rainfall and cold soil conditions. Use the leaf Nitrogen level to determine primary Nitrogen requirement.

2) Trifoliolate & Citrumelo rootstocks are very sensitive to limestone and should not be planted in soils containing limestone. Other rootstock are moderately sensitive to limestone. Ascertain the rootstock tolerance prior to planting.

FRUIT GROWERS LABORATORY, INC.

CEL:JRJ

Chad Lessard, Director of Ag. Services

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www.fglinc.com

July 12, 2011

Patty Frazer

102 Ravenhill Road
Orinda, CA 94563

Lab ID : SP 1105923-003

Customer ID : 2-23787

Sampled On : May 23, 2011

Sampled By : Payton Carling

Received On : June 13, 2011

Depth : N/A

Meth Irrg. :

Description : VTF

Project : Payton Carling/Cal Poly Thesis

WASHINGTON SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation				
				Very Low	Moderately Low	Optimum	Moderately High	Very High
Primary Nutrients								
Nitrate-Nitrogen	19.6	Lbs/AF	40 - 80	<div></div>				
Phosphorus-P ₂ O ₅	55	Lbs/AF	140 - 280	<div></div>				
Potassium-K ₂ O (Exch)	2300	Lbs/AF	640 - 3800	<div></div>				
Potassium-K ₂ O (Sol)	66.7	Lbs/AF	94 - 470	<div></div> 3%				
Secondary Nutrients								
Calcium (Exch)	18500	Lbs/AF	16000 - 22000	<div></div>				
Calcium (Sol)	169	Lbs/AF	160 - 640	<div></div> 17%				
Magnesium (Exch)	4090	Lbs/AF	1600 - 3300	<div></div>				
Magnesium (Sol)	105	Lbs/AF	73 - 220	<div></div> 17%				
Sodium (Exch)	1160	Lbs/AF	0.0 - 1600	<div></div>				
Sodium (Sol)	748	Lbs/AF	0.0 - 800	<div></div> 4%				
Sulfate	207	Lbs/AF	120 - 3800	<div></div>				
Micro Nutrients								
Zinc	0.800	Lbs/AF	4.0 - 160	<div></div>				
Manganese	18.8	Lbs/AF	6.0 - 240	<div></div>				
Iron	18.8	Lbs/AF	40 - 200	<div></div>				
Copper	2.00	Lbs/AF	1.2 - 41	<div></div>				
Boron	1.32	Lbs/AF	1.2 - 8.4	<div></div>				
Chloride	525	Lbs/AF	14 - 660	<div></div>				
CEC	34.0	meq/100g	14 - 35	<div></div>				
% Base Saturation								
CEC - Calcium	67.9	%	60 - 80	<div></div>				
CEC - Magnesium	24.8	%	10 - 20	<div></div>				
CEC - Potassium	3.59	%	1.0 - 6.0	<div></div>				
CEC - Sodium	3.71	%	0.0 - 5.0	<div></div>				
CEC - Hydrogen	0.00	%	0.0 - 3.0	<div></div>				
				Strongly Acidic	Moderately Acidic	Near Neutral	Moderately Alkaline	Strongly Alkaline
pH	8.18	---	6.0 - 7.5	<div></div>				

Good Problem Indicates physical conditions and/or phenological and amendment requirements.

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Mobile: (559) 737-2399

July 12, 2011

Patty Frazer

Lab ID : SP 1105923-003

Customer ID : 2-23787

Description : VTF

WASHINGTON SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation									
Others				Satisfactory		Possible Problem		Moderate Problem		Increasing Problem			
Soil Salinity	1.22	mmhos/cm	0.0 - 2.0	<div></div>									
SAR	5.6		0.0 - 6.0	<div></div>									
Limestone	1.4	%	0.0 - 0.50	<div></div>									
				0	1	2	3	4	5	6			
Lime Requirement	0	Tons/AF	---	<div></div>									
				Very Low		Moderately Low		Optimum		Moderately High			
Moisture	6.5	%	3.3 - 23	<div></div>									
				Loamy Sand	Sandy Loam	Loam	Silt Loam	Clay Loam	Clay	Organic			
Saturation	33.1	%	40 - 50	<div></div>									
				Mineral				Organic					
% Organic Matter	1.39	%	---	<div></div>									

Good Problem Indicates physical conditions and/or phenological and amendment requirements.

Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

1) The need for soil Nitrate is dependant upon crop phenology (Growth Stage) and crop requirement. A soil Nitrate level of 10 - 40 ppm is preferred for a short time during critical periods of uptake into the tree. It is highly desirable to have low soil Nitrate (< 5ppm) prior to winter rainfall and cold soil conditions. Use the leaf Nitrogen level to determine primary Nitrogen requirement.

2) Trifoliolate & Citrumelo rootstocks are very sensitive to limestone and should not be planted in soils containing limestone. Other rootstock are moderately sensitive to limestone. Ascertain the rootstock tolerance prior to planting.

FRUIT GROWERS LABORATORY, INC.

CEL:JRJ

Chad Lessard, Director of Ag. Services

FRUIT GROWERS LABORATORY, INC.

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July 12, 2011

Patty Frazer

102 Ravenhill Road
Orinda, CA 94563

Lab ID : SP 1105923-004

Customer ID : 2-23787

Sampled On : May 23, 2011

Sampled By : Payton Carling

Received On : June 13, 2011

Depth : N/A

Meth Irrg. :

Description : Control

Project : Payton Carling/Cal Poly Thesis

WASHINGTON SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation				
				Very Low	Moderately Low	Optimum	Moderately High	Very High
Primary Nutrients								
Nitrate-Nitrogen	23.2	Lbs/AF	40 - 80	<div></div>				
Phosphorus-P ₂ O ₅	64	Lbs/AF	140 - 280	<div></div>				
Potassium-K ₂ O (Exch)	2410	Lbs/AF	640 - 3900	<div></div>				
Potassium-K ₂ O (Sol)	65.2	Lbs/AF	94 - 470	<div></div> 3%				
Secondary Nutrients								
Calcium (Exch)	18600	Lbs/AF	16000 - 22000	<div></div>				
Calcium (Sol)	159	Lbs/AF	160 - 640	<div></div> 17%				
Magnesium (Exch)	4120	Lbs/AF	1700 - 3300	<div></div>				
Magnesium (Sol)	95.3	Lbs/AF	73 - 220	<div></div> 16%				
Sodium (Exch)	1180	Lbs/AF	0.0 - 1600	<div></div>				
Sodium (Sol)	700	Lbs/AF	0.0 - 780	<div></div> 64%				
Sulfate	173	Lbs/AF	120 - 3800	<div></div>				
Micro Nutrients								
Zinc	0.800	Lbs/AF	4.0 - 160	<div></div>				
Manganese	19.2	Lbs/AF	6.0 - 240	<div></div>				
Iron	20.0	Lbs/AF	40 - 200	<div></div>				
Copper	2.40	Lbs/AF	1.2 - 41	<div></div>				
Boron	1.32	Lbs/AF	1.2 - 8.4	<div></div>				
Chloride	396	Lbs/AF	14 - 660	<div></div>				
CEC	34.2	meq/100g	14 - 35	<div></div>				
% Base Saturation								
CEC - Calcium	67.8	%	60 - 80	<div></div>				
CEC - Magnesium	24.8	%	10 - 20	<div></div>				
CEC - Potassium	3.74	%	1.0 - 6.0	<div></div>				
CEC - Sodium	3.74	%	0.0 - 5.0	<div></div>				
CEC - Hydrogen	0.00	%	0.0 - 3.0	<div></div>				
				Strongly Acidic	Moderately Acidic	Near Neutral	Moderately Alkaline	Strongly Alkaline
pH	8.16	---	6.0 - 7.5	<div></div>				

Good Problem Indicates physical conditions and/or phenological and amendment requirements.
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Mobile: (559) 737-2399

July 12, 2011

Patty Frazer

Lab ID : SP 1105923-004

Customer ID : 2-23787

Description : Control

WASHINGTON SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation									
Others				Satisfactory		Possible Problem		Moderate Problem		Increasing Problem			
	Soil Salinity	1.10	mmhos/cm	0.0 - 2.0	<div></div>								
	SAR	5.4		0.0 - 6.0	<div></div>								
	Limestone	1.0	%	0.0 - 0.50	<div></div>								
				0	1	2	3	4	5	6			
Lime Requirement	0	Tons/AF	---	<div></div>									
				Very Low	Moderately Low		Optimum		Moderately High		Very High		
Moisture	7.2	%	3.4 - 24	<div></div>									
				Loamy Sand	Sandy Loam	Loam	Silt Loam	Clay Loam	Clay	Organic			
Saturation	34.2	%	40 - 50	<div></div>									
				Mineral				Organic					
% Organic Matter	1.43	%	---	<div></div>									

Good Problem Indicates physical conditions and/or phenological and amendment requirements.

Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

1) The need for soil Nitrate is dependant upon crop phenology (Growth Stage) and crop requirement. A soil Nitrate level of 10 - 40 ppm is preferred for a short time during critical periods of uptake into the tree. It is highly desirable to have low soil Nitrate (< 5ppm) prior to winter rainfall and cold soil conditions. Use the leaf Nitrogen level to determine primary Nitrogen requirement.

2) Trifoliolate & Citrumelo rootstocks are very sensitive to limestone and should not be planted in soils containing limestone. Other rootstock are moderately sensitive to limestone. Ascertain the rootstock tolerance prior to planting.

FRUIT GROWERS LABORATORY, INC.

CEL:JRJ

Chad Lessard, Director of Ag. Services

FRUIT GROWERS LABORATORY, INC.

Analytical Chemists
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July 12, 2011

Patty Frazer

102 Ravenhill Road
Orinda, CA 94563

Lab ID : SP 1105923-007

Customer ID : 2-23787

Sampled On : May 23, 2011

Sampled By : Payton Carling

Received On : June 13, 2011

Depth : N/A

Meth Irrg. :

Description : Hurricane Effected Orchard

Project : Payton Carling/Cal Poly Thesis

WASHINGTON SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation				
				Very Low	Moderately Low	Optimum	Moderately High	Very High
Primary Nutrients								
Nitrate-Nitrogen	32.4	Lbs/AF	40 - 80	<div><div></div></div>				
Phosphorus-P ₂ O ₅	55	Lbs/AF	140 - 280	<div><div></div></div>				
Potassium-K ₂ O (Exch)	3670	Lbs/AF	1000 - 6300	<div><div></div></div>				
Potassium-K ₂ O (Sol)	40.5	Lbs/AF	94 - 470	<div><div></div>1%</div>				
Secondary Nutrients								
Calcium (Exch)	26100	Lbs/AF	27000 - 36000	<div><div></div></div>				
Calcium (Sol)	156	Lbs/AF	160 - 640	<div><div></div>11%</div>				
Magnesium (Exch)	7870	Lbs/AF	2700 - 5400	<div><div></div></div>				
Magnesium (Sol)	114	Lbs/AF	73 - 220	<div><div></div>13%</div>				
Sodium (Exch)	4880	Lbs/AF	0.0 - 2600	<div><div></div></div>				
Sodium (Sol)	1280	Lbs/AF	0.0 - 810	<div><div></div>76%</div>				
Sulfate	507	Lbs/AF	120 - 3800	<div><div></div></div>				
Micro Nutrients								
Zinc	1.20	Lbs/AF	4.0 - 160	<div><div></div></div>				
Manganese	18.0	Lbs/AF	6.0 - 240	<div><div></div></div>				
Iron	39.6	Lbs/AF	40 - 200	<div><div></div></div>				
Copper	3.60	Lbs/AF	1.2 - 41	<div><div></div></div>				
Boron	4.24	Lbs/AF	1.2 - 8.4	<div><div></div></div>				
Chloride	1080	Lbs/AF	14 - 660	<div><div></div></div>				
CEC	56.0	meq/100g	14 - 35	<div><div></div></div>				
% Base Saturation								
CEC - Calcium	58.0	%	60 - 80	<div><div></div></div>				
CEC - Magnesium	28.9	%	10 - 20	<div><div></div></div>				
CEC - Potassium	3.48	%	1.0 - 6.0	<div><div></div></div>				
CEC - Sodium	9.48	%	0.0 - 5.0	<div><div></div></div>				
CEC - Hydrogen	0.00	%	0.0 - 3.0	<div><div></div></div>				
				Strongly Acidic	Moderately Acidic	Near Neutral	Moderately Alkaline	Strongly Alkaline
pH	8.34	---	6.0 - 7.5	<div><div></div></div>				

Good Problem Indicates physical conditions and/or phenological and amendment requirements.

Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

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July 12, 2011

Patty Frazer

Lab ID : SP 1105923-007

Customer ID : 2-23787

Description : Hurricane Effected Orchard

WASHINGTON SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation														
Others				Satisfactory			Possible Problem			Moderate Problem			Increasing Problem					
	Soil Salinity	1.87	mmhos/cm	0.0 - 2.0	<div></div>													
	SAR	9.5		0.0 - 6.0	<div></div>													
	Limestone	2.1	%	0.0 - 0.50	<div></div>													
				0	1	2	3	4	5	6								
Lime Requirement	0	Tons/AF	---	<div></div>														
				Very Low			Moderately Low			Optimum			Moderately High			Very High		
Moisture	4.2	%	3.5 - 25	<div></div>														
				Loamy Sand	Sandy Loam	Loam	Silt Loam	Clay Loam	Clay	Organic								
Saturation	35.2	%	40 - 50	<div></div>														
				Mineral						Organic								
% Organic Matter	1.71	%	---	<div></div>														

Good Problem Indicates physical conditions and/or phenological and amendment requirements.

Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

- 1) The need for soil Nitrate is dependant upon crop phenology (Growth Stage) and crop requirement. A soil Nitrate level of 10 - 40 ppm is preferred for a short time during critical periods of uptake into the tree. It is highly desirable to have low soil Nitrate (< 5ppm) prior to winter rainfall and cold soil conditions. Use the leaf Nitrogen level to determine primary Nitrogen requirement.
- 2) Trifoliolate & Citrumelo rootstocks are very sensitive to limestone and should not be planted in soils containing limestone. Other rootstock are moderately sensitive to limestone. Ascertain the rootstock tolerance prior to planting.

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Chad Lessard, Director of Ag. Services

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July 12, 2011

Patty Frazer102 Ravenhill Road
Orinda, CA 94563

Lab ID : SP 1105923-005

Customer ID : 2-23787

Sampled On : May 23, 2011-:

Sampled By : Payton Carling

Received On : June 13, 2011-16:00

Matrix : Compost

Description : Worm Castings

Project : Payton Carling/Cal Poly Thesis

ORGANIC AMENDMENT ANALYSIS

Constituent	Units	Dried	As Received	Lbs./cu.yd As Received	Lbs./Ton As Received
Total Nitrogen	%	1.95	0.796	7.45	15.9
Total Phosphorus (P ₂ O ₅)	%	1.63	0.665	6.23	13.3
Total Potassium (K ₂ O)	%	1.29	0.526	4.93	10.5
Total Chloride	%	0.225	0.0918	0.86	1.84
Total Sodium	%	0.286	0.117	1.09	2.33
Boron	ppm	77.2	31.5	0.0295	0.063
Calcium	%	2.90	1.18	11.1	23.7
Magnesium	%	0.938	0.383	3.59	7.65
Zinc	ppm	50.3	20.5	0.0192	0.041
Manganese	ppm	259	106	0.099	0.211
Iron	ppm	2600	1060	0.994	2.12
Copper	ppm	17	6.94	0.0065	0.0139
Salinity (EC)	mmhos/cm		10.1		
pH	units		8.39		
Moisture	%		59.2		
Organic Matter	%	40.8	16.6		
Ash	%	59.2	24.2		
Bulk Density	Lbs/yd ³		937		
Carbon	%	23.6	9.63	90.2	193
Carbon:Nitrogen	Ratio		12.1		

Reviewed and
Approved By**Chad Lessard**Digitally signed by Chad Lessard
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July 12, 2011

Patty Frazer102 Ravenhill Road
Orinda, CA 94563

Lab ID : SP 1105923-006

Customer ID : 2-23787

Sampled On : May 23, 2011-:

Sampled By : Payton Carling

Received On : June 13, 2011-16:00

Matrix : Compost

Description : Compost

Project : Payton Carling/Cal Poly Thesis

ORGANIC AMENDMENT ANALYSIS

Constituent	Units	Dried	As Received	Lbs./cu.yd As Received	Lbs./Ton As Received
Total Nitrogen	%	1.10	0.793	6.32	15.9
Total Phosphorus (P ₂ O ₅)	%	1.44	1.04	8.27	20.8
Total Potassium (K ₂ O)	%	1.09	0.786	6.26	15.7
Total Chloride	%	0.225	0.162	1.29	3.24
Total Sodium	%	0.240	0.173	1.38	3.46
Boron	ppm	39.1	28.2	0.0225	0.0564
Calcium	%	3.23	2.33	18.6	46.6
Magnesium	%	0.571	0.412	3.28	8.23
Zinc	ppm	41.0	29.6	0.0236	0.0591
Manganese	ppm	212	153	0.122	0.306
Iron	ppm	2810	2030	1.61	4.05
Copper	ppm	11.9	8.58	0.00684	0.0172
Salinity (EC)	mmhos/cm		16.4		
pH	units		7.52		
Moisture	%		27.9		
Organic Matter	%	16.3	11.8		
Ash	%	83.7	60.3		
Bulk Density	Lbs/yd ³		797		
Carbon	%	9.47	6.83	54.4	137
Carbon:Nitrogen	Ratio		8.61		

Reviewed and
Approved By**Chad Lessard**Digitally signed by Chad Lessard
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June 9, 2011
Patty Frazer
102 Ravenhill Road
Orinda, CA 94563

Lab ID : SP 1105542-001
Customer ID : 2-23787
Sampled On : May 27, 2011
Sampled By : Payton Carling
Received On : June 6, 2011
Age : Mature
Meth Irrg. :

Description : C+VTF Navel
Project : Payton Carling/Cal Poly Thesis

WASHINGTON PLANT TISSUE ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation				
Macro Nutrients				Deficient	Low	Ample	High	Excessive
Total Nitrogen (Leaf)	2.60	%	2.6 - 2.8	<div></div>	<div></div>			
Phosphorus (Leaf)	0.53	%	0.12 - 0.21	<div></div>	<div></div>			
Potassium (Leaf)	1.38	%	0.70 - 3.3	<div></div>	<div></div>			
Calcium (Leaf)	4.14	%	3.0 - 5.5	<div></div>	<div></div>			
Magnesium (Leaf)	0.41	%	0.26 - 0.60	<div></div>	<div></div>			
Micro Nutrients								
Zinc (Leaf)	16.5	ppm	25 - 200	<div></div>				
Manganese (Leaf)	19	ppm	25 - 300	<div></div>				
Iron (Leaf)	44	ppm	60 - 200	<div></div>				
Copper (Leaf)	12	ppm	5.0 - 40	<div></div>	<div></div>			
Boron (Leaf)	160	ppm	31 - 300	<div></div>	<div></div>			
Sodium (Leaf)	0.222	%	0.0 - 0.16	<div></div>	<div></div>	<div></div>	<div></div>	

Good Problem Indicates physical conditions and/or phenological and amendment requirements.

Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

These standards are based on a dry weight basis in 5 to 7 month old navels, bloom cycle leaves from non-fruiting, non-flushing terminals. Adapted and revised from Jones and Embleton, University of California. The optimum range for total nitrogen in navel oranges as listed is based on FGL laboratory information and is higher than that for valencia oranges. All leaves and/or petioles are thoroughly washed prior to drying.

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June 9, 2011
Patty Frazer
102 Ravenhill Road
Orinda, CA 94563

Lab ID : SP 1105542-002
Customer ID : 2-23787
Sampled On : May 27, 2011
Sampled By : Payton Carling
Received On : June 6, 2011
Age : Mature
Meth Irrg. :

Description : GMCC+VTF Navel
Project : Payton Carling/Cal Poly Thesis

WASHINGTON PLANT TISSUE ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation				
				Deficient	Low	Ample	High	Excessive
Macro Nutrients								
Total Nitrogen (Leaf)	2.48	%	2.6 - 2.8	<div><div></div></div>				
Phosphorus (Leaf)	0.51	%	0.12 - 0.21	<div><div></div></div>				
Potassium (Leaf)	1.64	%	0.70 - 3.3	<div><div></div></div>				
Calcium (Leaf)	3.69	%	3.0 - 5.5	<div><div></div></div>				
Magnesium (Leaf)	0.38	%	0.26 - 0.60	<div><div></div></div>				
Micro Nutrients								
Zinc (Leaf)	16.3	ppm	25 - 200	<div><div></div></div>				
Manganese (Leaf)	22	ppm	25 - 300	<div><div></div></div>				
Iron (Leaf)	43	ppm	60 - 200	<div><div></div></div>				
Copper (Leaf)	11	ppm	5.0 - 40	<div><div></div></div>				
Boron (Leaf)	134	ppm	31 - 300	<div><div></div></div>				
Sodium (Leaf)	0.151	%	0.0 - 0.16	<div><div></div></div>				

Good Problem Indicates physical conditions and/or phenological and amendment requirements.

Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

These standards are based on a dry weight basis in 5 to 7 month old navels, bloom cycle leaves from non-fruiting, non-flushing terminals. Adapted and revised from Jones and Embleton, University of California. The optimum range for total nitrogen in navel oranges as listed is based on FGL laboratory information and is higher than that for valencia oranges. All leaves and/or petioles are thoroughly washed prior to drying.

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June 9, 2011
Patty Frazer
102 Ravenhill Road
Orinda, CA 94563

Lab ID : SP 1105542-003
Customer ID : 2-23787
Sampled On : May 27, 2011
Sampled By : Payton Carling
Received On : June 6, 2011
Age : Mature
Meth Irrg. :

Description : VTF Navel
Project : Payton Carling/Cal Poly Thesis

WASHINGTON PLANT TISSUE ANALYSIS

WASHINGTON TEAM FISH REAPERS								
Test Description	Result	Units	Optimum Range	Graphical Results Presentation				
				Deficient	Low	Ample	High	Excessive
Macro Nutrients								
Total Nitrogen (Leaf)	2.33	%	2.6 - 2.8	<div></div>				
Phosphorus (Leaf)	0.42	%	0.12 - 0.21	<div></div>				
Potassium (Leaf)	1.54	%	0.70 - 3.3	<div></div>				
Calcium (Leaf)	3.78	%	3.0 - 5.5	<div></div>				
Magnesium (Leaf)	0.40	%	0.26 - 0.60	<div></div>				
Micro Nutrients								
Zinc (Leaf)	14.6	ppm	25 - 200	<div></div>				
Manganese (Leaf)	22	ppm	25 - 300	<div></div>				
Iron (Leaf)	45	ppm	60 - 200	<div></div>				
Copper (Leaf)	10	ppm	5.0 - 40	<div></div>				
Boron (Leaf)	143	ppm	31 - 300	<div></div>				
Sodium (Leaf)	0.234	%	0.0 - 0.16	<div></div>				

Good Problem Indicates physical conditions and/or phenological and amendment requirements.

Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

These standards are based on a dry weight basis in 5 to 7 month old navels, bloom cycle leaves from non-fruiting, non-flushing terminals. Adapted and revised from Jones and Embleton, University of California. The optimum range for total nitrogen in navel oranges as listed is based on FGL laboratory information and is higher than that for valencia oranges. All leaves and/or petioles are thoroughly washed prior to drying.

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June 9, 2011
Patty Frazer
102 Ravenhill Road
Orinda, CA 94563

Lab ID : SP 1105542-004
Customer ID : 2-23787
Sampled On : May 27, 2011
Sampled By : Payton Carling
Received On : June 6, 2011
Age : Mature
Meth Irrg. :

Description : Control Navel
Project : Payton Carling/Cal Poly Thesis

WASHINGTON PLANT TISSUE ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation				
Macro Nutrients				Deficient	Low	Ample	High	Excessive
Total Nitrogen (Leaf)	1.89	%	2.6 - 2.8	<div></div>				
Phosphorus (Leaf)	0.56	%	0.12 - 0.21	<div></div>				
Potassium (Leaf)	1.21	%	0.70 - 3.3	<div></div>				
Calcium (Leaf)	4.64	%	3.0 - 5.5	<div></div>				
Magnesium (Leaf)	0.42	%	0.26 - 0.60	<div></div>				
Micro Nutrients								
Zinc (Leaf)	15.0	ppm	25 - 200	<div></div>				
Manganese (Leaf)	22	ppm	25 - 300	<div></div>				
Iron (Leaf)	46	ppm	60 - 200	<div></div>				
Copper (Leaf)	11	ppm	5.0 - 40	<div></div>				
Boron (Leaf)	182	ppm	31 - 300	<div></div>				
Sodium (Leaf)	0.117	%	0.0 - 0.16	<div></div>				

Good Problem Indicates physical conditions and/or phenological and amendment requirements.

Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

These standards are based on a dry weight basis in 5 to 7 month old navels, bloom cycle leaves from non-fruiting, non-flushing terminals. Adapted and revised from Jones and Embleton, University of California. The optimum range for total nitrogen in navel oranges as listed is based on FGL laboratory information and is higher than that for valencia oranges. All leaves and/or petioles are thoroughly washed prior to drying.

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May 24, 2011
Patty Frazer
102 Ravenhill Road
Orinda, CA 94563

Lab ID : SP 1104701-002
Customer ID : 2-23787
Sampled On :
Sampled By : Payton Carling
Received On : May 12, 2011
Matrix : Non Potable Water

Description : San Isidro Canal Water
Project : Cal Poly SLO Masters Thesis

General Irrigation Suitability Analysis

Test Description	Result				Graphical Results Presentation				
	mg/L	Meq/L	% Meq	Lbs/AF	Good	Possible Problem	Moderate Problem	Increasing Problem	Severe Problem
Cations									
Calcium	22	1.1	14	60	**				
Magnesium	19	1.6	20	52	**				
Potassium	4	0.1	1	11	**				
Sodium	114	5	64	310					
Anions									
Carbonate	< 10	0	0	0					
Bicarbonate	220	3.6	48	600	**				
Sulfate	19	0.4	5	52	**				
Chloride	121	3.4	46	330					
Nitrate	< 0.4	0	0	0					
Fluoride	0.5	0.026	0	1					
Minor Elements									
Boron	0.40			1.1					
Copper	< 0.01			0.00					
Iron	< 0.05			0.00					
Manganese	0.020			0.054					
Zinc	0.040			0.11					
TDS by Summation	520			1400					
Other									
pH	8.2			units					
E. C.	766			umhos/cm					
SAR	4.3								
Crop Suitability									
No Amendments	Fair								
With Amendments	Fair								
Amendments									
Gypsum Requirement	0.7			Tons/AF	Do not apply if Sulfuric Acid amendment is applied. Or 30 oz/1000Gal of urea Sulfuric Acid (15/49).				
Sulfuric Acid (98%)	13			oz/1000Gal					
Leaching Requirement	5.8			%					

Good Problem Indicates physical conditions and/or phenological and amendment requirements.
Note: Color coded bar graphs have been used to provide you with "AT-A-GLANCE" interpretations.

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May 24, 2011

Patty Frazer

Lab ID : SP 1104701-002

Customer ID : 2-23787

Description : San Isidro Canal Water

Micro Irrigation System Plugging Hazard

Test Description	Result		Graphical Results Presentation		
			Slight	Moderate	Severe
Chemical					
Manganese	0.02	mg/L
Iron	< 0.05	mg/L
TDS by Summation	520	mg/L
No Amendments					
pH	8.2	units
Alkalinity	180	mg/L
Total Hardness	133	mg/L
With Amendments					
Alkalinity	36	mg/L
Total Hardness	36	mg/L
pH	5.4 - 6.7	units

Good Problem Indicates physical conditions and/or phenological and amendment requirements.
 Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

Water Amendments Application Notes:

The Amendments recommended on the previous pages include:

Gypsum:

This should be applied at least once a year to the irrigated soil surface area. Gypsum can also be applied in smaller quantities in the irrigation water. Apply the smaller (bracketed) amount of gypsum when also applying the recommended amount of Sulfuric Acid and the larger amount when applying only Gypsum.

Sulfuric Acid:

These products should be applied as needed to prevent emitter plugging in micro irrigation systems and/or as a soil amendment to adjust soil pH to improve nutrient availability and to facilitate leaching of salts. Please exercise caution when using this material as excesses may be harmful to the system and/or the plants being irrigated. The reported Acid requirement is intended to remove approximately 80 % of the alkalinity. The final pH should range from 5.4 to 6.7. We recommend a field pH determination to confirm that the pH you designate is being achieved. This application is based upon the use of a 98% Sulfuric Acid product. The application of Urea Sulfuric Acid is based upon the use of a product that contains 15% Urea (1.89 lbs Nitrogen), 49% Sulfuric Acid and has a specific gravity of 1.52 at 68 °F. Guidelines for the above interpretations are sourced from USDA & U.C. Cooperative Extension Service publications. Please contact us if you have any questions.

FRUIT GROWERS LABORATORY, INC.

Chad Lessard, Director of Ag. Services

CEL:EHB

FRUIT GROWERS LABORATORY, INC.

Analytical Chemists
www.fglinc.com

May 24, 2011
Patty Frazer
102 Ravenhill Road
Orinda, CA 94563

Lab ID : SP 1104701-003
Customer ID : 2-23787
Sampled On :
Sampled By : Payton Carling
Received On : May 12, 2011
Matrix : Non Potable Water

Description : Worm Tea
Project : Cal Poly SLO Masters Thesis

General Irrigation Suitability Analysis

Test Description	Result				Graphical Results Presentation				
	mg/L	Meq/L	% Meq	Lbs/AF	Good	Possible Problem	Moderate Problem	Increasing Problem	Severe Problem
Cations									
Calcium	124	6.2	6	340	**				
Magnesium	123	10	10	330	**				
Potassium	1960	50	50	5300	**				
Sodium	789	34	34	2100					
Anions									
Carbonate	60	2	2	160					
Bicarbonate	3240	53	46	8800	**				
Sulfate	300	6.2	5	820	**				
Chloride	1720	49	42	4700					
Nitrate	270	4.4	4	730					
Fluoride	< 5	0	0	0					
Minor Elements									
Boron	2.0			5.4					
Copper	0.050			0.14					
Iron	0.68			1.8					
Manganese	0.50			1.4					
Zinc	0.22			0.60					
TDS by Summation	8590			23000					
Other									
pH	8.3			units					
E. C.	11500			umhos/cm					
SAR	12.0								
Crop Suitability									
No Amendments	Poor								
With Amendments	Poor								
Amendments									
Gypsum Requirement	14.2			Tons/AF	Do not apply if Sulfuric Acid amendment is applied. Or 470 oz/1000Gal of urea Sulfuric Acid (15/49).				
Sulfuric Acid (98%)	190			oz/1000Gal					
Leaching Requirement	460			%					

Good Problem Indicates physical conditions and/or phenological and amendment requirements.
Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

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May 24, 2011

Patty Frazer

Lab ID : SP 1104701-003

Customer ID : 2-23787

Description : Worm Tea

Micro Irrigation System Plugging Hazard

Test Description	Result		Graphical Results Presentation		
			Slight	Moderate	Severe
Chemical					
Manganese	0.5	mg/L
Iron	0.68	mg/L
TDS by Summation	8590	mg/L
No Amendments					
pH	8.3	units
Alkalinity	2750	mg/L
Total Hardness	815	mg/L
With Amendments					
Alkalinity	550	mg/L
Total Hardness	550	mg/L
pH	5.4 - 6.7	units

Good Problem Indicates physical conditions and/or phenological and amendment requirements.
Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' Interpretations.

Water Amendments Application Notes:

The Amendments recommended on the previous pages include:

Gypsum:

This should be applied at least once a year to the irrigated soil surface area. Gypsum can also be applied in smaller quantities in the irrigation water. Apply the smaller (bracketed) amount of gypsum when also applying the recommended amount of Sulfuric Acid and the larger amount when applying only Gypsum.

Sulfuric Acid:

These products should be applied as needed to prevent emitter plugging in micro irrigation systems and/or as a soil amendment to adjust soil pH to improve nutrient availability and to facilitate leaching of salts. Please exercise caution when using this material as excesses may be harmful to the system and/or the plants being irrigated. The reported Acid requirement is intended to remove approximately 80 % of the alkalinity. The final pH should range from 5.4 to 6.7. We recommend a field pH determination to confirm that the pH you designate is being achieved. This application is based upon the use of a 98% Sulfuric Acid product. The application of Urea Sulfuric Acid is based upon the use of a product that contains 15% Urea (1.89 lbs Nitrogen), 49% Sulfuric Acid and has a specific gravity of 1.52 at 68 °F. Guidelines for the above interpretations are sourced from USDA & U.C. Cooperative Extension Service publications. Please contact us if you have any questions.

FRUIT GROWERS LABORATORY, INC.

Chad Lessard, Director of Ag. Services

CEL:EHB

APPENDIX B

Statistical Analysis of Fruit Yield and Tree Size

▼ **Oneway Analysis of fruit kilos By treatment**

▼ **Oneway Anova**

▼ **Summary of Fit**

Rsquare	0.491285
Adj Rsquare	0.436779
Root Mean Square Error	4.559868
Mean of Response	5.658438
Observations (or Sum Wgts)	32

▼ **Analysis of Variance**

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
treatment	3	562.2386	187.413	9.0135	0.0002*
Error	28	582.1870	20.792		
C. Total	31	1144.4256			

▼ **Means for Oneway Anova**

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
con	8	3.8625	1.6122	0.560	7.165
cvtf	8	12.8750	1.6122	9.573	16.177
gmcc	8	3.3250	1.6122	0.023	6.627
vtf	8	2.5713	1.6122	-0.731	5.874

Std Error uses a pooled estimate of error variance

▼ Oneway Analysis of fruit # By treatment

▼ Oneway Anova

▼ Summary of Fit

Rsquare	0.485536
Adj Rsquare	0.430415
Root Mean Square Error	31.08234
Mean of Response	36.65625
Observations (or Sum Wgts)	32

▼ Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
treatment	3	25530.094	8510.03	8.8085	0.0003*
Error	28	27051.125	966.11		
C. Total	31	52581.219			

▼ Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
con	8	23.3750	10.989	0.86	45.89
cvtf	8	85.2500	10.989	62.74	107.76
gmcc	8	22.8750	10.989	0.36	45.39
vtf	8	15.1250	10.989	-7.39	37.64

Std Error uses a pooled estimate of error variance

▼ Oneway Analysis of tree height By treatment						
▼ Oneway Anova						
▼ Summary of Fit						
Rsquare		0.068528				
Adj Rsquare		-0.03127				
Root Mean Square Error		0.594143				
Mean of Response		2.55625				
Observations (or Sum Wgts)		32				
▼ Analysis of Variance						
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
treatment	3	0.727175	0.242392	0.6866	0.5678	
Error	28	9.884175	0.353006			
C. Total	31	10.611350				
▼ Means for Oneway Anova						
Level	Number	Mean	Std Error	Lower 95%	Upper 95%	
con	8	2.58500	0.21006	2.1547	3.0153	
cvtf	8	2.78000	0.21006	2.3497	3.2103	
gmcc	8	2.49375	0.21006	2.0635	2.9240	
vtf	8	2.36625	0.21006	1.9360	2.7965	
Std Error uses a pooled estimate of error variance						

▼ Oneway Analysis of circumference By treatment						
▼ Oneway Anova						
▼ Summary of Fit						
Rsquare		0.216619				
Adj Rsquare		0.132685				
Root Mean Square Error		1.921615				
Mean of Response		8.873438				
Observations (or Sum Wgts)		32				
▼ Analysis of Variance						
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
treatment	3	28.59001	9.53000	2.5808	0.0734	
Error	28	103.39291	3.69260			
C. Total	31	131.98292				
▼ Means for Oneway Anova						
Level	Number	Mean	Std Error	Lower 95%	Upper 95%	
con	8	8.6075	0.67939	7.2158	9.999	
cvtf	8	10.3813	0.67939	8.9896	11.773	
gmcc	8	8.7313	0.67939	7.3396	10.123	
vtf	8	7.7738	0.67939	6.3821	9.165	
Std Error uses a pooled estimate of error variance						

APPENDIX C

Photo Essay of the Experiment

Experimental Site

The Cadegomo Oasis Valley, San Isidro, Baja California Sur, Mexico

San Isidro Irrigation Canal

San Isidro Irrigation Dam

Irrigating the WNO Experimental Orchard

C+VEF Treatment WNO Under Irrigation

Sweet Clovers Growing in the Alley of
the WNO Experimental Orchard

Sweet Clover Partially Cut for Livestock Feed

Compost

Compost Site Before Construction

Completed Compost Pile

Finished Compost Pile, Compost Pile Turned
Once and Recently Constructed Piles

All Compost Covered to Retain Moisture

Shoveling Compost for WNO Tree Application

Full Wheelbarrow Taken from
Finished Compost Piles

Compost Applied Under WNO Tree

The Farm Horses Contributed Manure for Compost

Cows in the Corral Contributed
Manure for the Compost

Milking Goats on the Farm Contributed
Manure for the Compost

Legume Cover Crop

Black-Eyed Pea Seeds

Black-Eyed Peas Growing Under WNO Tree

Faba Bean Seeds

Faba Beans Growing Under WNO Tree

Dry Pea Seeds

Dry Peas Growing Under WNO Tree

Vermicompost Extract Foliar

Vermicompost Table 1

Vermicompost Table 2

Red Wiggler Worms (*Eisenia fetida*)

Red Wiggler Worms (*Eisenia fetida*)

Applying Water to Vermicompost Table 1

Vermicompost Extract Being Collected in Bucket

Fine Spraying Vermicompost Extract
on WNO Tree Upper Foliage

Stream Spraying Vermicompost Extract
on WNO Tree Upper Foliage

Washington Navel Orange Trees in Experiment

Compost and Vermicompost Extract Foliar

C+VEF 1

C+VEF 2

C+VEF 3

C+VEF 4

C+VEF 5

C+VEF 6

C+VEF 7

C+VEF 8

Legume Cover Crop and Vermicompost Extract Foliar

LCC+VEF 1

LCC+VEF 2

LCC+VEF 3

LCC+VEF 4

LCC+VEF 5

LCC+VEF 6

LCC+VEF 7

LCC+VEF 8

Vermicompost Extract Foliar

VEF 1

VEF 2

VEF 3

VEF 4

VEF 5

VEF 6

VEF 7

VEF 8

Control

Control 1

Control 2

Control 3

Control 4

Control 5

Control 6

Control 7

Control 8

Google Earth Photo of Experimental WNO Orchard

All Treatments of the Experiment were Implemented on WNO Trees within this Orchard Randomly