Effects of different mulching techniques for improving irrigation water use efficiency and yields for cherry tomato produced by Del Cabo farm in Baja California, México

By

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Under the supervision of Dr. Ir. J.M.S. Scholberg

Department of farming systems ecology

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This study was performed in collaboration with Del Cabo

Abstract

Maintaining optimal soil water content through the growing season of tomatoes (*Lycopersicon esculentum*) is required for optimal plant growth and yield especially in sandy soils and hot regions. The objective of this study was to evaluate different management techniques to increase soil water status, enhance water use efficiency, plant performance, crop yield and fruit quality. Treatments included the use of different compost rates (low [6 t/ha] vs high [30 t/ha]) in combination with different mulching techniques such as garlic straw applied at 3.5 kg/m^2, oat straw applied at 3 kg/m^2, plastic mulch (standard management practices) and no mulch. Soil moisture monitoring techniques employed included using tensiometer and soil moisture sensors. Plant performance (plant height, canopy density and canopy volume) were monitored at weekly interval, together with crop yield (specific fruit weight and weekly yields) and fruit quality (brix degrees and fruit size). Use of plastic mulch or Garlic straw with extra compost treatment appeared to perform significantly better in terms of overall plant growth parameters. In terms of crop yield, plastic mulch together with oat mulch treatment had the best performance. Regarding fruit quality parameters, fruit size tended to decrease overtime and for brix degrees plastic and oat mulch only showed significantly higher values during one harvesting date whereas values were similar during the remainder of the growing season. Overall plastic mulch resulted on a better yield and plant performance but garlic straw mulch together with high compost resulted overall in better soil moisture retention when compared to garlic straw and plastic mulch. It is concluded that the use of straw mulch has the potential to increase soil water retention and may also increase yields and improve soil quality but additional research is needed to look at long-term benefits in terms of fruit yield, soil quality, potential water savings and profitability.

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1. Introduction

1.1. Del Cabo Farm

Larry Jacobs, the co-founder of Del Cabo farm was born in 1950 in San Fernando Valley, California. When he was young he used to own a tree nursery but he started to have problems with aphids, then he started to apply pesticides but he started to feel ill by using them. As a solution he learned about the IPM method, which he found to be really interesting and effective. Later on Jacobs went to study soil science at the California Polytechnic State University in San Luis Obispo. After graduation he met his now wife Sandra Belin, they move together to Pescadero, California where in 1980 they founded Jacobs Farm, which is now the largest organic culinary herb producer in the United States (Reti 2010).

In 1986 Larry and Sandra started Del Cabo organic growers association together with a cooperative of family farmers in Baja California, Mexico. After this merger the company was called Jacobs Farm/Del Cabo, and it created a new international market for organic vegetables, mainly for cherry tomatoes. They export mainly to the U.S market, but also to Iceland and Dubai. They export around 19 million pounds of cherry tomatoes and other vegetables. Besides just buying the product from different farmers, Del Cabo is an organization that links small-scale farmers with markets, provides advanced and appropriate technology, which includes all aspects of organic production, postharvest handling, packaging, and offers the farmers materials and a working capital to start. In this manner Del Cabo is ensuring that the small-scale farmers will get the best return from their products. They have assisted over 400 farming families and their communities. In 2009 Jacobs Farm/ Del Cabo had a total of 1500 ha of field-grown crops and 9 ha of greenhouses (Reti 2010).Del Cabo has two main production groups:

- In the North of Baja California: Shown in **Error! Reference source not found.**

Figure 1 Production areas in the North of Baja California 1: Ojos Negros; 2: Maneadero; 3: Santa Rosa; 4: La Misión; 5: San Vicente; 6: San Quintín.

In the South of Baja California: Shown in

- Figure

Figure 3 Production units in the South of Baja California: 1 San Jose; 2: Boca Sierra; 3: Santa Cruz; 4: Las Cuevas; 5: La Ribera; 6: Mulege; 7: Vizcaino.

1.2. Organic tomato in México

Organic cherry tomato (*Lycopersicon esculentum)* is the principal crop that is grown by Del Cabo farms at Baja California, Mexico. They also grow Roma tomatoes and Heirloom tomatoes.

In Mexico, the total production of tomato was 2.26 millions of tons in 2008. Sinaloa is the principal state producer of tomato in Mexico accounting for 35% of production volume while Baja California is the second state generating 9% of the total national production. In the United States 80% of the total imported tomato volume comes from Mexico. Globally, Mexico occupies the second place among the world exporting nations for fresh market tomato with 18%, while the Netherlands occupies the first place accounting for 22% (Sagarpa et al., 2010).

Organic tomato production in Mexico has increased over the past years. The production of organic cherry tomato as it can be seen in Table 1 is increasing every year but is still low compared to the conventional cherry tomato production.

Table 1 shows the production (T) of organic and conventional tomato crops in Mexico from 2004 to 2008.

Table 1 Tomato production in México (Tons) (SAGARPA et al., 2010)

	2004	2005	2006	2007	2008
Organic cherry tomato	684	2,797	2,909	4,061	5,119
Organic tomato	3,800	350	18,118	6,008	22,801
Conventional cherry tomato	54,592	59,107	44,480	36,017	34,847

1.3. Challenges faced by Del Cabo farm

Based on the results of (Martinez 2013) and based on an interview of the production manager of Del Cabo farm, there is a need to develop management practices that can address the main problems that Del Cabo farm experience. These include, low inherent soil fertility (soil organic matter), limited water availability and high temperatures.

The difference between the current and the attainable production levels of tomato are related to yield limiting factors prevailing throughout the region as related to availability of water and nutrients. The excessively high temperatures prevailing in Ojos Negros, during the summer, also affect the potential production levels.

The aquifer in Ojos Negros is the only source of water available for agricultural activities in this area. The CNA (Comisión Nacional del Agua) has calculated the mean annual depletion, which is about 6.5 hm^3. The groundwater depletion has measurable effects on climate, soils, vegetation and on other elements of the ecosystem. Moreover, water is a very limiting factor in Del Cabo farm, as annual rainfall tends to be low (240 mm) and the company is now facing a really critic situation and is required to start developing new techniques for improving water use efficiency.

1.4. Monitoring techniques for maintaining soil water moisture

Adequate soil moisture supply is required to ensure an optimal yield for tomato. Monitoring soil moisture therefore is needed and should be integral part of improved irrigation management techniques for making more efficient use of limited water resources and to ensure high tomato production (Zotarelli, Dukes et al. 2009).

1.4.1 Compost

Compost is a stable humus material created by mixing organic waste in proper ratios together with having control of temperature, oxygen and moisture, which will accelerate the decomposition of the organic material. The decomposition is made by bacteria and fungi, which utilize the organic materials as a source of food and energy. Mature compost can improve soil structure, nutrient holding capacity, water infiltration and drought tolerance while it reduces fertilizer requirements and can increase microbial and earthworm populations (Christian, Evanylo et al. 2009).

Compost is incorporated in all Del Cabo production units. The compost used in Del Cabo is a product named TIKEL, which is made from a mixture of manure, fish waste, gypsum, wood chips and other organic materials. TIKEL, a solid compost developed for use in intensive agriculture, it is only used at Del Cabo as a pre-plant fertilizer and it is normally applied at 6 t/ha. This compost is certified by OMRI.

1.4.2 Mulching

Plastic mulch can enhance fruit quality, weed control and also contributes to more efficient use of irrigation water and plant nutrients applied via fertigation (Lamont 1996). In terms of the use of plastic mulch in Del Cabo farm, the plastic mulch they use is 25 microns thick and 1.12 m wide. The plastic mulch covers the whole production bed and only a hole is made where the transplant can be inserted.

The plastic colors that are currently used in Del Cabo farm operation are:

- Black mulch in winter and in the early spring
- Silver/black mulch in spring and autumn
- White/black mulch in summer

The color of the plastic mulch is important because it determines its radiation, the surface temperature and the underlying soil temperature. It creates a microclimate around the crop (Lament 1993).The reflected energy from the mulch can affect plant growth, fruit yields and the behavior of insects that can get repel or attract by the color of the plastic mulch (Csizinszky, Schuster et al. 1995).

Organic mulches such as straw, hay, grass or leaf matter can provide multiple benefits for organic farms. They are capable of suppressing weeds, of regulating soil moisture and soil surface temperatures. They improve overall soil quality by increasing organic matter of the soil, soil porosity, water holding capacity while also stimulating soil life and increasing nutrient availability (Diver, Kuepper et al. 2012).

Use of organic mulch such as straw can reduce soil temperature beneath the mulch more effectively as when compared to the use of black plastic mulch. Use of straw mulch also results in higher soil moisture than plastic mulch while it also increases soil potassium levels (Truax and Gagnon 1993). Tomatoes grown in a hairy vetch mulch can produce up to 85% of a maximum yield without using any N fertilizer and tomatoes plants continue also to produce 2 to 3 weeks longer than tomatoes grown with black plastic mulch (Abdul-Baki and Teasdale 1997).

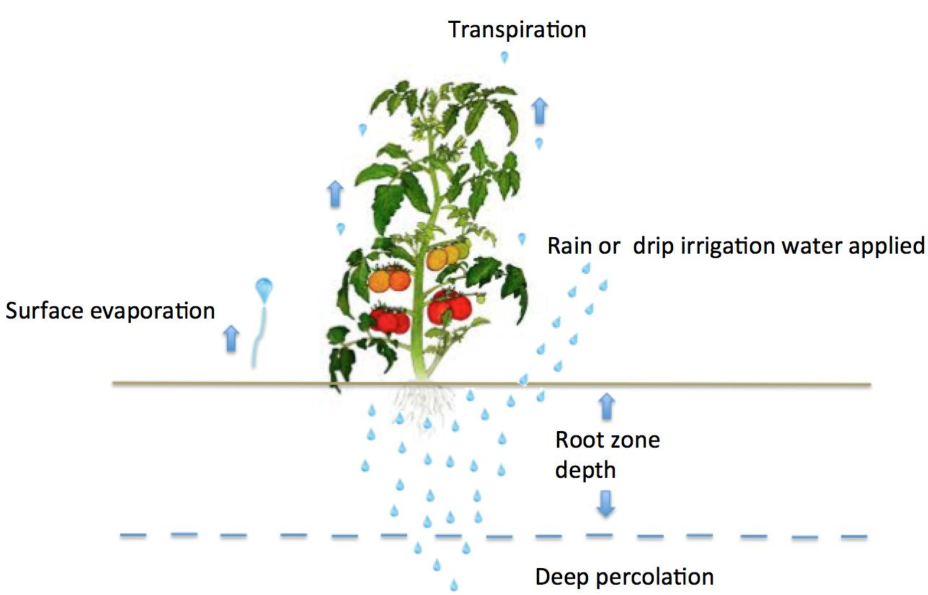
1.5. Drip irrigation

In Del Cabo farm drip irrigation is commonly used, with fields being irrigated every other day for approximately 3 hours depending on the temperature, plants size and the soil moisture status. About 25 m3 of water per hour is applied which translates to 2.5 mm.

The current drip tape used by Del Cabo is named Aqua-Traxx with a proportional balanced cross section (PBX) from a company called TORO. This is a premium choice for drip irrigation because it offers a proportionally balanced design that optimizes water flow, by reducing its turbulence and delivering a uniform distribution and it also reduces clogging. The drip tape used had an emmiter spacing of 20 cm, a diameter of 16 mm, a wall thickness of 0.127 mm and a flow/discharge rate of 1.02 (lph).

The clogging of drip emitters is the largest problem with drip systems (Capra and Scicolone 2004).To prevent emitters from clogging, when installed emitters should face upward, while also an appropriate filter should be used to remove particles suspended in the water that can clog emitters and only completely soluble fertilizers should be used. The used of certified organic fertilizers based on seaweed or fish emulsions may also increase the risk of emitter clogging. To have a maintenance prevention program of the drip irrigation system is the best way to prevent emitters from clogging (Simonne, Hochmuth et al. 2014) because when clogging occurs completely or just in some parts, irrigation uniformity is reduced and therefore irrigation efficiency is decreased as well (Capra and Scicolone 2004). In Del Cabo Farm they only used the drip tapes one season. Each new growing season they used new ones to prevent problems with built up of precipitated solids and clogging of emitters.

During irrigation, the crop may not effectively use the water applied. Effective crop water utilization mainly depends on the amount of water applied as related to specific crop water requirements and specific application techniques (Burt, Clemmens et al. 1997). The next system diagram, **Error! Reference source not found.** shows how water may be lost from a tomato ystem via leaching, transpiration and evaporation. Via mulching evaporative water losses may be reduced while its suppression of weed growth may also reduce overall crop water requirements.



Using drip irrigation increases irrigation water use efficiency while it can also minimize nitrate leaching. The irrigation amount required for attaining maximum tomato productivity ranges from 80% to 109% of class A pan evaporation (Hartz 1993). However, in the case of del Cabo it appears that there is still room for improvement in terms of irrigation scheduling. The use of organic amendments could enhance soil water retention and plant-based mulches could be used as a natural alternative to plastic mulch.

Figure 2 The plant/soil/water cycle

2. Purpose of the study

2.1. Objectives of Research

The aim of this study is to analyze and evaluate different techniques that enhance water use efficiency and crop yield. Techniques such as monitoring soil moisture, the use of different amounts of compost and different mulching practices. Each technique will be evaluated on its ability to reduce soil temperature and to increase soil moisture. Moreover, beneficial effects on soil organic matter, water use efficiency and tomato yield on Del Cabo farm will also be evaluated.

2.2. Research questions

The following research questions are being addressed:

1) What is the effect of plastic mulch compared to different organic mulches on water use efficiency, crop growth and yield of fresh market tomato at del Cabo farm?

2) What is the effect of not using mulch compared to using different organic mulches and plastic mulch on water use efficiency, crop growth and yield of fresh market tomato at del Cabo farm?

3) Can high amounts of compost enhance water use efficiency and thereby increase yield?

4) Can frequently monitoring soil moisture increase water use efficiency and yields at Del Cabo farm?

2.3. Hypotheses

- Tomato yields will be higher with organic mulch and this effect will be especially pronounced in hot regions (Schonbeck and Evanylo 1998)

- Straw mulch will increase soil organic matter content and will also ameliorated plant stress related to high temperature and low soil moisture more effectively compared to the use of plastic mulch (Tindall, Beverly et al. 1991)

- Increased application of organic amendments will increase SOM content which in turn is positively correlated with soil water retention capacity (Celik, Ortas et al. 2004)

- Monitoring soil moisture tension or soil moisture content can elucidate potential problems related to irrigation water management that might negatively affect crop yield or water use (Hanson, Orloff et al. 2000)

- There is a clear correlation between cumulative water use and yields

3. Materials and Methods

3.1. Field site

Del Cabo farm is a cooperative that maintains a working relationship with over 400 small farmers. The small farmers are spread along the whole peninsula of Baja California in Mexico. The experimental field was located in Ojos Negros, which is located in the Northern part of the peninsula of Baja California, close to the city of Ensenada (31°55’09’’ N; 116°14’01’’W), about 80 miles south of the Mexico-US border. The main economic activities in the valley are livestock and crop production. The mean annual temperature is 16.8 C° with a mean annual precipitation of 240 mm (Group 2003).

Figure 3 Panoramic view of the valley of Ojos Negros, Baja California, México

Figure 4 Ojos Negros, Production area in Baja California, México

A soil texture and content analysis of the experimental field was made before the experiment started by a commercial laboratory, Complete results are shown in appendix A.

Table 2. Complete results are shown in appendix A.

Table 2 Physical and biochemical soil parameters of the experimental site

Parameter	Soil type Sandy loam
Sand (%)	*69.3*
Silt (%)	*17.8*
Clay (%)	*12.9*
pH	*6.60*
Sodium absorption ratio	*2.90*
Base saturation %	*60.8*
Electric Conductivity (dS/m)	*1.03*
Total Soluble Salts (ppm)	*659*
Organic matter (%)	*1.70*

3.2. Experimental design and management

A randomized complete block design was employed first with five different treatments (T1-T5), only for measuring plant growth parameters (plant height, canopy density and canopy volume). For crop yield, fruit quality and WUE measurements two more different treatments where incorporated to the experiment (T6 and T7). Each treatment had a total of 3 replicates. A complete field design is shown in **Error! Reference source not found.**, with a total of 3 plots. ach plot consisted of 3 rows of tomato. Within each plot 7 sections of 6 tomato plants were closely monitored. The measurements for plant performance were taken only from 3 plants from each section within the plot, and plants were selected at the beginning of the data analysis. The crop yield measurements and the fruit quality mesurements together with the WUE were taken from all the 6 plants from each of the seven section per plot.

The treatments are the following:

- Plastic mulch (standard management practices) **(T1)**
- Garlic straw mulch **(T2)**
- Oat straw mulch **(T3)**
- Garlic straw mulch C (high compost) **(T4)**
- Oat straw mulch + C (high compost) **(T5)**
- No mulch **(T6)**
- No mulch + C (high compost) **(T7)**

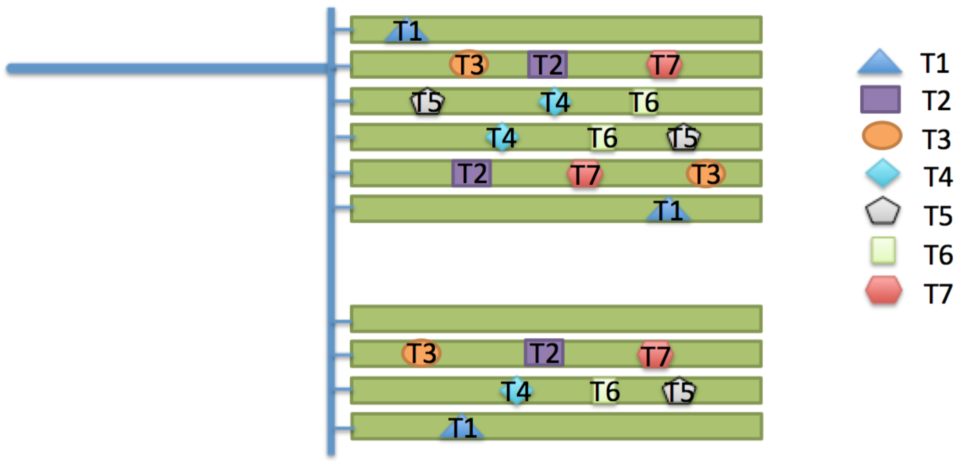


Figure 6 Experimental layout, mulching techniques for water use efficiency

Experimental included three different organic amendments: A) garlic straw used as a mulch, B) Oat straw used as a mulch, c) Compost applied at 6 vs 30 t per ha (high compost). The treatments that were being implemented included either one or more of these amendments except for the conventional plastic and no-mulched controls.

Del Cabo farm production unit in Ojos Negros includes a total of 43 hectares. The 43 hectares are segregated into production plots, each plot is identified by a given number, this for a better management of the farm. The plot with the number 55 is where this experimental took place. Each bed was prepared and raised before the plastic and organic mulch were applied. The plot 55 had a total of 47 beds each 90 m long, the bed spacing (center to center) was 1.8 m and the raised section had a width of approximately 0.40 m.

Tomato plants were transplanted on June 17th and mulch application occurred on the same day. The variety of tomato used is called AMAI, which is a grape tomato from SAKATA Seed Company. The plant density of plants was 18518 plants per hectare, with a distance of 30 cm between each plant in the row and 180 cm between each row. However, plant density is reduce to 14814 plants per hectare, because on average 20 % of each hectare is used for growing other plants as natural barriers, such as maize and sunflower.

Representative samples of the organic mulch were collected prior to application and sent to a commercial laboratory for a foliar analysis of the macro and micronutrients, results of the main parameters of Oat and Garlic are presented in Table 3. Complete results are shown in Appendix B.1 and B.2.

Table 3 Nitrogen, phosphorus and potassium content (expressed as percentage) of the organic mulch materials used

Nutrient content (%)	Oat	Garlic
N	1.75	1.47
P	0.89	0.66
K	3.70	5.00

The total amount of Oat straw applied was 3 kg per m^2 while the total amount of Garlic straw applied was 3.5 kg per m^2. The field with the mulch can be seen in **Error! Reference source ot found.**.

Figure 5 Experimental field with mulch

3.2.3 Main machinery used and its function

Tractor-based plow: served as the main machinery for primary tillage (plowing). It helps prepare the soil, incorporate residues, and control weeds.

Bed shapers: this equipment creates the raised soil beds, which allow plants develop better and use more efficient the organic fertilizers.

Disk harrow: its function is to turn and loose the top layer of the soil and also can be used to partially incorporate and cut remaining crop residues.

Sulfur sprayer: its function is to spread sulfur to the plant, in order to combat some diseases.

Trenchers: its function is to make furrows in the fields that are going to be used for plantation or use for making furrows for drainage.

Sprayer: its function is to make the application of organic fertilizers, insecticides, repellents, etc.

Plastic mulch layer: its function is to make the beds; it also installs the irrigation tape together with the plastic mulch over the beds.

Fertilizer spreader: it's used for the application and incorporation of organic fertilizers in the soil.

3.2.4 Fertilization

Fertilization in Del Cabo production unit starts with a base (pre-plant) fertilization application, together with the incorporation of crop residues from preceding crops. In this research the amount of compost TIKEL applied was changed for the high compost treatments from 6000 kg/ha, which is standard rate to 30000 kg/ha, used as the high compost treatments. Table 4 shows the soil amendments used as a pre-plant fertilization in this experiment.

Table 4 Amendments apply at pre-planting and its composition

Soil amendment	***Amount applied (kg/ha)***	***N %***	***P %***	***K %***
Compost (TIKEL)	6000/30000	3.44	1.78	3.98
Phosphate rock	520	0	12	0
Crab meal	520	2.95	1.40	.48
Gypsum	1050	0	0	0
Guano	560	7.70	11.36	4.16

In addition to the pre-planting fertilization there were weekly fertilizer application, which is given by the production managers. It consists of different organic fertilizers, growing enhancers and a compost tea that is produce in the farm. These products are applied mainly through the drip-irrigation system (fertigation) while a few are applied as a foliar spray. A complete list of products can be seen in Appendix B

The compost tea is a valuable product for the farm itself because since is used, it has increased plant performance. It is an important source of nutrients and microorganism for the plants, and it is applied every week via a 50 to 100 L per ha per application, depending on the plant growth stage. Compost tea is created in the farm, first by filling ¾ of water of the final volume used of 2500 lt., then a combination of different products are mixed and put in the water together with molasses, finally the microorganisms are incorporated and are left for fermentation for 3 days. A water pump is needed the 3 days for aerating the mix, which will permit the growth and reproduction of microorganism. The compost tea is applied within 24 hours after it has been ready, this to warrant optimal microorganisms performance. Table 7 shows the products that are typically used to create a fermented compost tea.

Table 7. Ingredients of the compost tea

Product	*Units*
Diamond K (Potassium) kms	2 kg
Humibac (Vermicompost)	14 kg
True organic	4 kg
Crab meal	14 kg
Phosphate rock	14 kg
Maya magic	7 L
Agrobacilos	10 L
Molasses	30 L
Algaenzims	12 L
Bio amin	12 L
Biosoil	6 L
Humega	12 L

3.3. Field data collection and calculations

During the tomato growing period the soil moisture was monitored weekly, just before an irrigation application, mainly in the morning. Fruit samples were taken for small field sections of 6 plants to determine crop yield and fruit quality (see 3.3.3 and 3.3.4). Water use efficiency was determined as crop yield per unit of water applied (Howell 2001).

For measuring WUE the next equation was used:

$$WUE_{1} = \text{(Tomato} \frac{\text{fresh yield (kg/ha)}}{\text{Water used (m3/ha)}} = \text{kg m}^{-3}$$

3.3.1 Monitoring soil moisture

The maintenance of the soil water content through all the tomatoes growing period is important to get an optimum plant growth and yield (Fares and Alva 2000). It is important to know the soil characteristics and soil profile when setting irrigation threshold (e.g. setpoints when to start irrigating and the amount of water applied per irrigation).   Values for a sandy loam soil the following values shown in Table 8 were assumed (Hanson, Orloff et al. 2000).

Table 8. Soil moisture characteristics expressed as volumetric water content for a sandy loam soil (%).

Sandy loam soil profile	
Permanent wilting point (%)	9
Field capacity (%)	21
Saturation (%)	40
Available soil moisture (%)	12
Maximum allowable depletion (%)	50
Irrigation threshold depletion (%)	15

For monitoring soil moisture the following techniques were used:

i. First, two small plastic buckets where installed, one at the beginning of the drip irrigation line and the other one at the end, each one below a drip emitter. Each bucket was cover by a piece of plastic mulch, a hole was made in to the plastic to let the drop of water get in and prevent it from evaporating once it was inside the bucket. The buckets where installed for the purposed of collecting water from every irrigation event to calculate this way the total amount of water that was being apply over time.

ii. Secondly, 3 tensiometers were install at the beginning of the production cycle at a depth of 15 cm. Readings of soil water tension (SWT) were taken daily, every morning.

iii. Thirdly, 3 Decagon dielectric volumetric water content sensors (Decagon Devices, Pullman, Washington State, USA) and a data logger were installed on 3 different treatments: on T1, T3 and T6. One was the EC-5 and the other two were the 5TM moisture sensors. The sensors use an electromagnetic field to measure the dielectric conductivity of the surrounding soil. The digital/analog data logger used was the EM50. **Error! Reference source not ound.** shows how the installation took place in the field. For installation a hole was made at a distance of 10-15 cm from the plant stem, then the sensors were placed under the roots, into the sidewall of the hole of the undisturbed soil. The metal prongs and central body of the sensors were buried completely and finally the hole was carefully backfilled to match the overall bulk density of the surrounding soil. Sensors were placed in the middle of each bed at a soil depth of 20 cm. Readings were taken every hour and measurements stored in the data logger. Every day data were downloaded from the data logger to a computer and data was imported into a, Microsoft excel data sheet in order to graph the data collected per week, which was used to monitor soil moisture within the experimental field.

Figure 6 Installation of decagon sensors and data logger

iv. Two buckets with a diameter of 30 cm were installed next to the bed at the beginning and at the end of the beds. The buckets were buried, only leaving the top 5 cm uncover of soil. A line inside the bucket was draw with a permanent marker at 5 cm from the rim to make sure that the bucket was leveled. Finally the bucket was cover with a chicken wire for preventing birds and other animals to drink the water from the bucket. **Error! Reference source not ound.** shows how the buckets were installed. The amount of water required to restore the water level to the original level was taken as a proxy for Weather-class A pan evaporation values and measures were taken once a week and used for Evapotranspiration calculation.

Figure 9 Example of bucket used for ET calculation

3.3.2 Plant performance

Three small sections of three plants each were selected randomly within each treatment. Each section was separated by two small flags, that were buried at the sides of the three plants. These sections were used for the following non-destructive measures:

- Plant height (cm), plant measurements of all the treatments were taken every week for 13 weeks. The plants were measure with a tape measure from the top of the soil up to the apical meristem of the plant. Values were also used for canopy volume calculations.

- Canopy diameter was measure with a tape measure for the first three weeks, once a week. Two measurements were taken from the top of the canopy, one of the length and the other of the width. Measures were also used for canopy volume calculations.

- Canopy density was measured weekly, starting week 5 until week 13 of the growing period. A scale was given where 1 equates to no leaves, and 10 signify a complete coverage of the soil by leaves.

Due to time constraints these measurements could not be recorded for the no-mulch and no mulch with high compost treatments.

3.3.2 Crop yield measurements:

Each field treatment was divided in sections. Each section had a total of 6 tomatoes plants as shown in **Error! Reference source not found.**. Sections were harvested at weekly ntervals. The weight, number and size of the harvested fruits were determined for each treatment and used to assess crop yield and crop quality. Number of tomatoes per weight was measure to determine the specific fruit weight as well.

Figure 7 Example of tomato section

3.3.3 Fruit quality

For measuring tomato quality, the following parameter were monitored:

- Fruit size (diameter), length and width of 10 representative tomatoes from each treatment were measured using a Digital Caliper. Data recorded was in mm and change to cm^3. Data was used for evaluating the uniformity of fruits as affected by different treatments.

- Brix degrees were used to evaluate the quality of the color of the tomatoes when harvested. Two ripening stages of tomatoes (4 and 5) from each treatment were used for measuring brix degrees, on these maturity stages tomatoes are normally harvested and sent to the packinghouse. The tomato juice was used for the analysis of the total soluble solid content expressed in Brix and determined with a refractometer. Each sample had a different stage of maturation, at stage 4 the color was between yellow and orange and at stage 5 the color was more orange but not fully red-colored tomatoes.

3.3.4 Statistical analysis

All the treatments were analyzed statistically on plant growth, crop yield, fruit quality and water use efficiency. Analysis was done using SPSS software (IBM 23 , SPSS, Inc., Chicago, IL). The ANOVA was performed at a ≤0.05 level of significance to determine if there was a significant difference between the different treatments. When a significant F-value was detected, comparison of means was carried out by the Tukey test.

4. Results and Discussion

4.1. Irrigation and soil water status

During this study the irrigation management of one of Del Cabo production units was evaluated. The complete data collected from all the irrigation events and the soil water status results measured with the tensiometers and the soil moisture sensors are shown In Appendix C.1, C.2 and C.3

4.1.1. Crop evapotranspiration (ET_C)

Crop evapotranspiration is estimated by multiplying the reference evapotranspiration (ETo) by the crop coefficient (Kc). ETo is best calculated by using the based Penman-Monteith equation(Amayreh and Al-Abed 2005). In this study ETo was determine with a bucket, by calculating the amount of water required to restore the original water level, this was taken as a proxy for Weather-class A pan evaporation values and measures were taken once a week. Results are shown in Table 5. The crop coefficient (Kc) values were retrieved from(Amayreh and Al-Abed 2005), were crop coefficient values under drip irrigation with plastic mulch were obtained by using the eddy covariance approach, which provides crop coefficients with high accuracy. Crop coefficients (Kc) were in general 31-40% lower than FAO values, this to the effect that provides drip irrigation together with plastic mulch.

Table 5 Crop evapotranspiration calculation

	Crop evapotranspiration (ET_C)					
Growth stages	Initial	Development	Midseason	Midseason	Late season	Total
Month	June	July	August	September	October	
Eto (mm/day)	5.9	6.74	6.3	6.2	4.14	
kc	0.42	0.65	0.83	0.83	0.52	
kc/month	0.19	0.46	1.0	0.8	0.43	
ETc (mm/day)	1.15	3.16	6.6	5.1	1.82	
ETc (mm/month)	17.3	126.4	131.8	154.3	36.4	466.0
Irrigation (mm/month)	18.0	108.0	134.6	171.2	34.2	466.2
Target (%)	104	85.4	102	110	93.9	

4.1.2. Irrigation application

The total amount of water apply was 466 mm/crop, rainfall was only 17 mm during the growing season. The total amount of water that the crops received was 483 mm/crop. The same volume of water was applied to all the treatments since it was not possible to modify the irrigation supply (as there as only one central valve) on an individual plot basis. The first irrigation event occurred on 17/06/2014, right after the tomatoes were transplanted and the last irrigation event occurred on the 20/10/14, when the plants were no longer economically productive. An overview of the irrigation events and the cumulative water applied is provided in **Error! eference source not found.**.

In terms of specific events during the tomato plant initial crop establishment stage (the first two weeks after transplant), the irrigation events typically amounted 22.0 mm, with a mean application of 2.7 mm per event and with an irrigation interval of 2-3 days.

The initial crop development stage started the 3rd of July and ended the 11th of August. During the crop development stage, the canopy closes and initial flowering and fruit set occurs. During this stage, the irrigation events amounted to a total of 116.4 mm, with a mean application of 5.0 mm per event while the irrigation application interval typically was 1-2 days. Precipitation was only 2.7 mm during this stage.

The mid-season stage started the 12th of August and ended the 8th of October. During this stage the canopy is fully developed and fruit expansion and maturation occurs and the bulk of water applied can be seen in **Error! Reference source not found.**. During these months the hottest emperatures of the growing season are being observed with a mean daily temperature in Ojos Negros of 24 °C while maximum values may be consistently above 30- 35°C. As the mid-season stage starts at the end of the crop development stage and lasts until maturity, the crop demands more water (Brouwer and Heibloem 1986). During the mid-season stage, the total irrigations events amounted to 293.4 mm, with a mean application of 6.1 mm per event and with an application interval of 1 day, except five events in where there was an interval of 2 days. Precipitation amount during this stage amounted to a total of 11 mm.

During the final crop development stage, which only lasted 12 days, the irrigation events amounted to a total of 34.2 mm with a mean application of 4.8 mm per event. The irrigation interval during this stage ranged from 1-3 days. Precipitation was only 2.7 mm during this stage.

Tomato crops in general are typically irrigated every other day, this because some days there was no water available, due to the need to apply water to other fields that where demanding more water. Based on the information outlined in Table 5, it appears that in general the seasonal irrigation application closely matched crop demand based on ET calculation. During crop development, irrigation application at times was a bit low and some (visual) crop stress was also observed as the soil at times became a bit dry (see discussion in section 4.1.3) . During mid-season irrigation appears to be a bit high and some leaching may have occurred. However, overall irrigation application appears to be in line with actual crop demand.

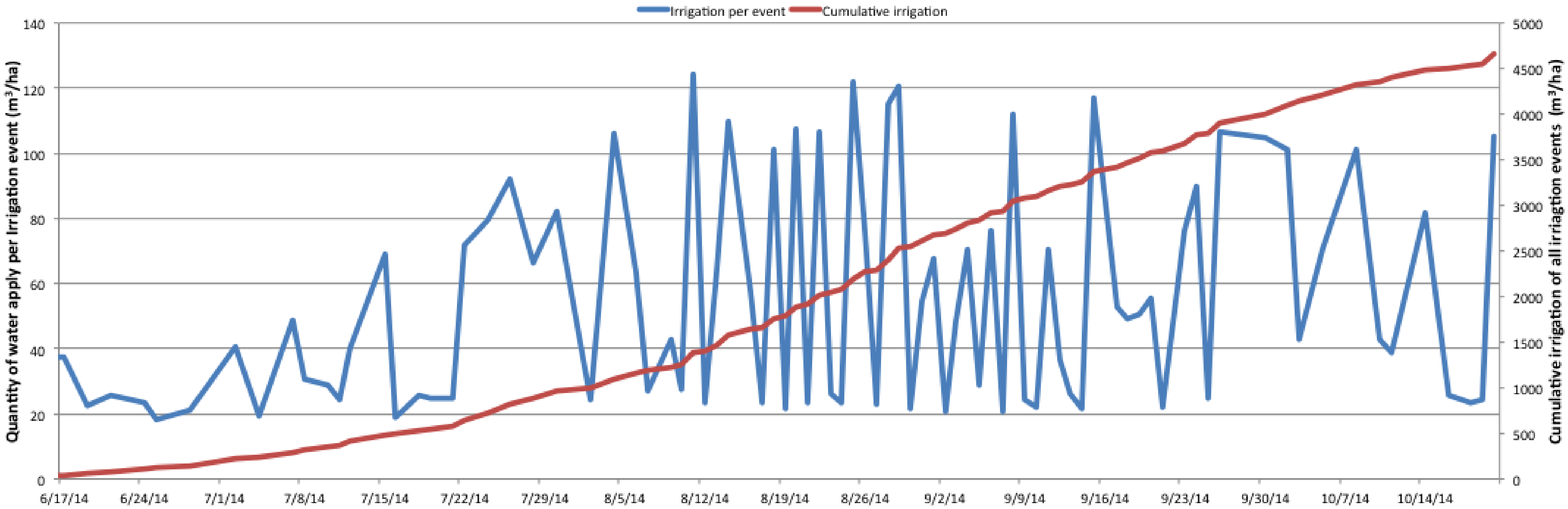


Figure 11 Amount of irrigation apply per event and cumulative irrigation (m^3/ha)

4.1.3. Soil Moisture Tension

Soil moisture tension readings in the upper soil profile (0-20 cm) from tensiometers where recorded daily for three different mulching techniques (plastic, straw, and straw + compost treatments). During the crop development stage (3 of July-11 of August), on three occasions a pronounced water deficit occurred. (7/22/14, 8/1/14 and the 8/11/14) which were also the highest soil moisture tension readings across the entire growing season (**Error! Reference ource not found.**). This is consistent with visual observation where plants showed mid-day wilting on this dates. Two of these dates (8/1/14 and the 8/11/14) showed readings around 80 cbar, which is well above the recommended threshold for irrigation, which is around 30 cbar for a sandy loamy soil.

The rest of the growing season the tomato crops didn't show any problems of stress and the soil water tension readings where between 5 and 30 cbar and didn't go higher. In similar findings by (Thompson, Gallardo et al. 2006) was observed that the soil matric potential in a well-watered treatment is generally maintained between 10 and 30 cbar.

Error! Reference source not found. shows that in general the plastic mulch treatment tended to ave higher soil water tension reading while the straw and high compost treatment generally had the lowest soil water tension readings. This can be because soil amendments, in this case the compost and the straw, may have reduced soil temperatures, while improve soil water holding capacity as reported by (Chanthai, Machikowa et al. 2012)

The results obtained are similar to findings by (Teasdale and Abdul-Baki 1995)where black plastic mulch increase soil temperature compared to organic mulch. On plastic mulch less than 10% of the radiation is reflected and the rest is absorbed. With organic mulch, radiation is not effectively transmitted due to the air space that is within the mulch, thereby less heat will be conducted from the mulch to the soil. Soil temperature thus may be affected by the composition and color of the mulch. The increase of temperature in the soil by plastic mulch can result in a decrease of soil moisture as reported by (Schonbeck and Evanylo 1998), who also reported that soil moistures was higher under organic mulch than under plastic mulch.

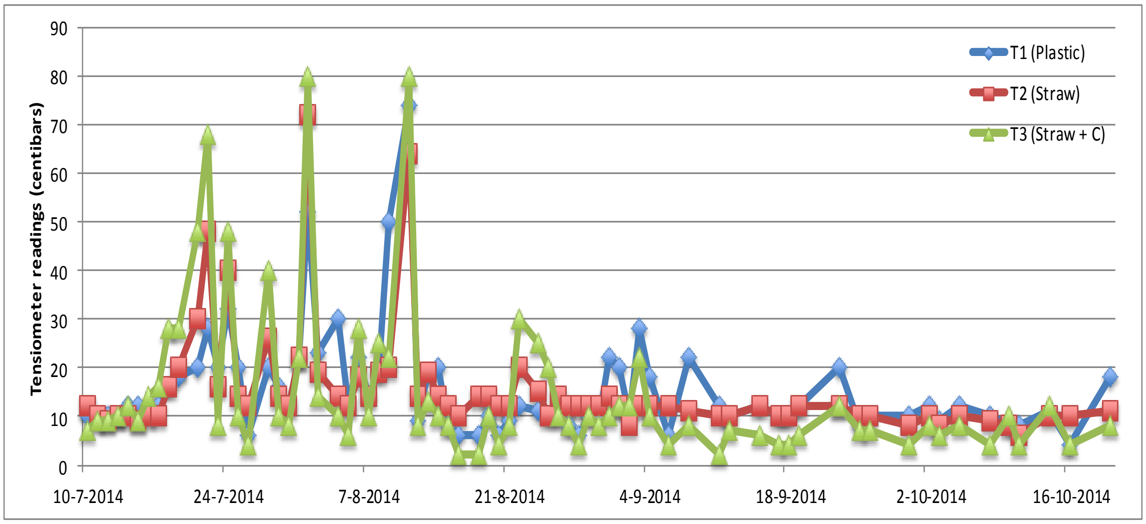


Figure 12 Tensiometer readings for plastic mulch, straw mulch and straw + C mulch

4.1.4. Soil moisture sensors

The water content in the upper soil profile (0-20 cm), based on reading from the dielectric sensors during the growing season is shown in **Error! Reference source not found.**. This graph hows peaks after each irrigation event. In this graph we can see that the straw mulch treatment appeared to have the highest volumetric water content values which seems to be in contrast with the findings for the tensiometer readings (Fig. 10). It thus may be possible that something was wrong with the sensor readings, as values are distinctly different from the other two treatments and the same irrigation rate was applied and crop performance was not that different. Similar to the tensiometer readings, the straw mulch + extra compost treatment performed better than plastic mulch. This may imply that the natural mulch can provide better water retention compared to the plastic mulch.

Similar findings were obtained by (Schonbeck and Evanylo 1998), where organic mulches compared to plastic mulch increase availability of soil moisture to the crop. However, in general actual soil moisture measurements don't reflect the moisture retention capacity of the soil within a certain cropping systems, because the water that is consumed by the plants may differ and is not measure. Thereby, if treatments conserve water, plants may grow more vigorously and as canopy size expands plants may comparatively consumed more water.

There was no calibration made to the sensors installed, sensors were installed using their factory calibration. The second sensor, in the straw mulch was a different model than the other two sensors. The sensors differ in dimensions and capability, but they all use the same technology and a frequency of 70MHz. (Limsuwat, Sakaki et al. 2009)reported that care must be taken when installing and calibrating the sensors, as the outputs values may differ, depending if the sensor head is inserted right on the material of interest or not. Calibration problems or installation may be the reason on why the second sensor readings were so different than the others.

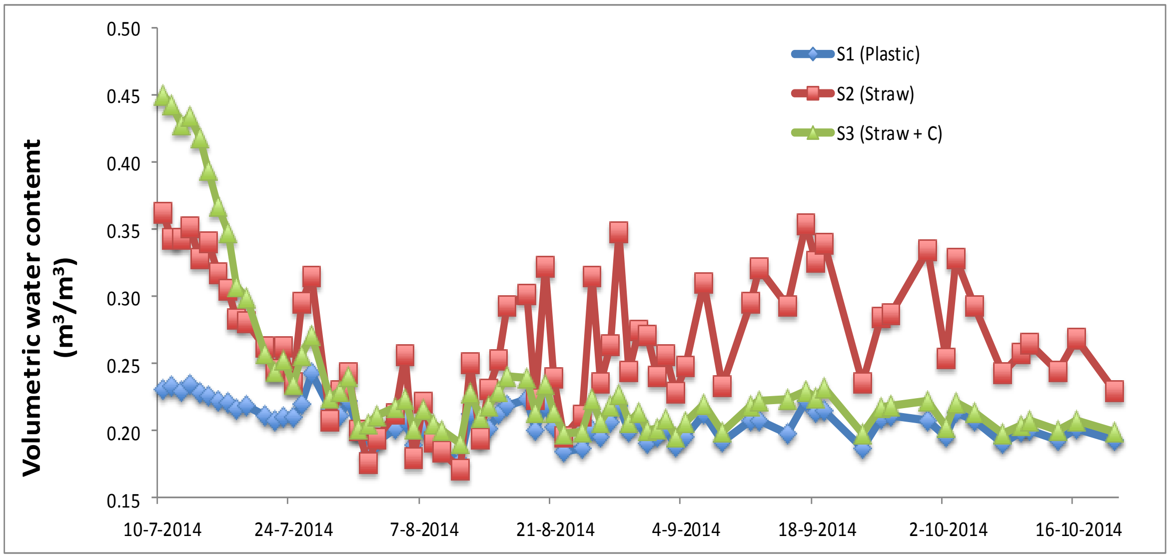


Figure 13 Sensor readings for plastic mulch, straw mulch and straw + C mulch (m^3/m^3)

4.2. Plant growth measurements

During this study three tomato plant growth measurements (plant height, canopy density and canopy volume) where made once a week, throughout the growing season. The complete data collected from all the plant growth measurements are shown in Appendix D.

4.2.1. Plant height

Plant heights for all treatments were measured weekly starting at 2 WAT to 13 WAT. The results, as shown in Table 6, show a significant difference in tomato plant height from the 5WAT to 8WAT and on 12WAT. The control, which is plastic mulch, had significantly taller plants between 5 and 8 WAT (Table 5). After this period differences became smaller where at 12 WAT the Oat treatment appeared to have shorter plants. This may have been related to the volunteering of oat seeds introduced in the field with the mulch that germinated and may have competed with the crop for water and nutrients. At 12WAT, plants for the garlic + extra compost treatment were numerically the tallest, but statistically plants still had similar heights compared to the control.

Similar findings were reported by (Mahajan, Sharda et al. 2007) who found that plants with plastic mulch grew taller as compared to straw mulch, this due to more effective weed control, improved water use efficiency and early plant growth associated with plastic mulch. Other findings reported by (Diver, Kuepper et al. 2012), showed that the use of organic mulch cools down the soil when temperatures are high and promotes soil-enhancing benefits, which is especially relevant for an organic systems and under adverse (excessively hot) conditions. With the use of plastic mulch soil temperature can be increased early in the season, promoting initial plant growth, but when temperatures increase, organic mulch may enhance plant growth by reducing soil temperature.

Table 6 Tomato plant height (cm) influenced by different mulching techniques

	Plant height (cm)											
	2WAT[1]	3WAT	4WAT	5WAT	6WAT	7WAT	8WAT	9WAT	10WAT	11WAT	12WAT	13WAT
Treatments (T)												
Plastic	19.6	34.2	61.0	84.6 a	105 a	125.8 a	140.4 a	149.9	157.4	160.9	165.0 a	170.2
Garlic	19.7	33.3	57.5	75.8 b	96.5 b	114.1 b	129.9 b	140.8	150.4	155.9	161.9 ab	166.5
Oat	20.2	31.9	55.6	72.8 b	93.2 b	112.1 b	129.8 b	141.3	148.5	148.7	157.8 b	164.5
Garlic + C	19.0	31.7	57.7	76.1 b	95.1 b	114.7 b	129.6 b	146.2	155.8	159.9	168.2 a	173.0
Oat + C	19.8	33.5	57.7	75.8 b	96.1 b	115.0 b	133.2 ab	146.1	153.0	158.3	167.7 a	171.2
Significance[2]	ns	ns	ns	***	***	***	*	ns	ns	ns	**	ns

1 WAT = weeks after transplanting.
2 *, ** and *** refer to *P* values < 0.05, < 0.01 and < 0.001, respectively; ns = not significant.

4.2.2. Canopy density

The scale used for assessing canopy density ranged from 1 to 10, and values were recorded starting 6WAT to 13WAT. The canopy density of each plant was measured for all treatments. The control (Plastic mulch) showed a significant higher value for canopy density during the first two weeks (6WAT and 7WAT) while later on (8-10WAT) there was no significance difference among treatments (Table 6). At the end of the growing season (> 11 WAP) Garlic + high compost treatment showed significantly greater canopy density values, but still had similar values to the mulched control. .

More vigorous canopy growth for the Garlic + high compost treatment is in line with findings from (Diver, Kuepper et al. 2012)who reported that plant growth is initially promoted first by plastic mulch early in the season but then later on the season when higher temperatures are reach organic mulch promotes more plant growth. In contrast (Choudhary, Bhambri et al. 2012)reported that the use of black plastic mulch compared to organic mulch increased the number of shoots and total leaf area.

Table 7 Canopy density (scale 1-10) influenced by different mulching techniques

	Canopy density (scale 1-10)							
	6WAT[1]	7WAT	8WAT	9WAT	10WAT	11WAT	12WAT	13WAT
Treatments (T)								
Plastic	6.1 a	7.1 a	7.5	7.4	7.5	7.4 ab	7.6 a	7.0 ab
Garlic	4.9 b	6.3 ab	6.9	7.3	7.3	7.5 ab	7.4 ab	7.1 ab
Oat	4.5 b	6.1 b	6.7	6.7	6.9	6.9 b	6.8 b	6.8 b
Garlic + C	5.3 ab	6.9 ab	7.4	7.3	7.4	7.7 a	7.7 a	7.6 a
Oat + C	5.3 ab	6.8 ab	7.3	7.1	7.2	7.5 ab	7.6 a	6.8 b
Significance[2]	**	**	ns	ns	ns	*	*	*

1 WAT = weeks after transplanting.
2 *, ** and *** refer to *P* values < 0.05, < 0.01 and < 0.001, respectively; ns = not significant.

4.2.3. Canopy volume

Canopy volume (cm^3), was obtained by measuring plant height (H), length (B) and width (A) of canopy cover from top of the photosynthetically active material assuming that volume is = 2/3 *H * pi * (A/2 *B/2) (Thorne, Skinner et al. 2002).

Initial canopy volume development was monitored at 2, 3 and 4 WAT but values were only significant different at 4WAT (Table 7). The control (plastic mulch) had significantly greater initial canopy development at 4WAT, while use of organic mulches tended to result in a 11-13% reduction in canopy volume. Among the organic amendments the application of high compost rates appears to initially decrease canopy expansion, as reflected in lower numeric values for canopy volume, although differences were not significant.

Similar findings were documented by (Asiegbu 1991), who reported that in a tomato experiment comparing different types of mulching, use of black plastic mulch resulted in a higher leaf area, when compared to other organic mulches. Black plastic mulch stimulates basal branching in field tomato, which greatly increases the sizes of leaf, stem, root and leaf area.

Table 8 Canopy volume (cm^3) influenced by different mulching techniques

	Canopy volume/ (cm^3)			
	2WAT[1]	3WAT	4WAT	
Treatment				
Plastic	4382	24040	100414	a
Garlic	4454	23442	80063	b
Oat	3932	20299	75413	b
Garlic + C	3829	19685	87785	ab
Oat +C	4269	22264	85508	ab
Significance	ns	ns	*	

1 WAT = weeks after transplanting.
2 *, ** and *** refer to *P* values < 0.05, < 0.01 and < 0.001, respectively; ns = not significant.

4.3. Crop yield measurements

During this study weekly yields were recorded together with specific fruit weight. Measurements where done for all treatments. The complete data collected is shown In Appendix E.

4.3.1. Weekly yields per treatment

The total cumulative yield per treatments was: for Plastic mulch 44.1 ton/ha, Garlic straw 34.9 ton/ha, Oat straw 39.5 tons/ha, Garlic straw + extra compost 41.7 ton/ha, Oat straw + extra compost 37.4, No mulch 35.1 and No mulch + extra compost 39.0 (Table 9). Overall plastic mulch had the higher final yield.

The weekly yield of each treatment was measured starting the 11WAT to 19WAT. The results, as shown Table 9 show a significant difference in tomato yield only at 11 and 13WAT. The No mulch + extra compost treatment had the highest initial yields, due to the excessively high temperature of the bare soil promoting the rate of ripening of the tomatoes. Other types of mulch tended to have higher soil moisture content values and probably also lower soil temperatures. Plastic mulch had significant higher on the 13WAT. Over all the use of natural mulches, resulted in a slight decline in yield as compared to the plastic mulched control. In the case of the current trial there were two main problems. The applied organic mulch material tended to blow away due to strong winds while the oat straw also contained some seeds that germinated and the volunteering plants thus became a weed.

In findings reported by (Mukherjee, Kundu et al. 2010), use of plastic mulch resulted in higher yields than organic mulch, due to the more efficient use of water and nutrients that it provides. Due to the good moisture conservation that it provides and the low population of weeds, that causes a reduction in competition for water and nutrient, due to the fact that no light can go through the mulch in compared to the organic mulch that some light can come through if it moves or if the mulch is not covering completely the soil. (Grassbaugh, Regnier et al. 2002)reported no significance difference in yield between organic mulch and plastic mulch, which means that organic mulch can be as effective as plastic mulch provided that the right materials is used and managed in an optimal manner. Which concurs with (Diver, Kuepper et al. 2012)who reported that organic mulch gave lower yields of tomato at the beginning of the harvesting season, but later yields were higher for the organic mulch compared to the plastic mulch. Use of organic mulch may also provide benefits due to higher soil moisture retention and greater cooling capacity during hot temperatures (Schonbeck and Evanylo 1998)

Table 9 Yield (tons/ha) influenced by different mulching techniques

	Yield (tons/ha)								
	11WAT[1]	12WAT	13WAT	14WAT	15WAT	16WAT	17WAT	18WAT	19WAT	TCY[2]
Treatments (T)										
Plastic	0.571 ab	7.72	9.89 a	8.20	3.36	3.07	5.38	2.85	3.09	44.1
Garlic	0.378 b	4.77	5.45 b	6.03	4.31	3.10	4.31	2.76	3.84	34.9
Oat	0.439 ab	6.56	6.66 ab	6.48	5.12	3.44	4.53	2.90	3.36	39.5
Garlic + C	0.307 b	5.51	5.73 b	9.24	4.62	3.72	5.79	3.39	3.39	41.7
Oat +C	0.438 ab	6.49	6.10 b	9.16	3.28	2.86	3.91	2.24	2.89	37.4
No mulch	0.284 b	5.31	5.55 b	6.48	4.45	2.46	4.11	2.90	3.87	35.1
No mulch + C	0.912 a	6.40	7.08 ab	8.34	3.13	2.45	4.18	3.41	3.10	39.0
Significance[3]	*	ns	*	ns	ns	ns	ns	ns	ns	

1 WAT = weeks after transplanting.
2 TCY = total cumulative yield
3 *, ** and *** refer to *P* values < 0.05, < 0.01 and < 0.001, respectively; ns = not significant.

4.3.2. Specific fruit weight

Specific fruit weight (average weight per fruit) was measured starting the 13WAT to 19WAT. Overall specific fruit weight was rather low due to the type of tomato grown and ranged from 2.6 to 4.6 gram per fruit. Specific fruit weight tended to decrease over time (Table 9). In terms of differences among treatment, the oat treatment had significantly larger fruits compared to the rest of the treatments at 14 and 15 WAT where as other treatments had intermediate values. During the rest of the growing seasons specific fruit weight was similar across all treatments.

(Abdul-Baki, Stommel et al. 1996)reported that plastic mulch and no mulch had similar specific fruit weight values while use of organic mulch enhanced fruit size, which concurs with findings by (Roberts and Anderson 1994)on pepper were the used of straw mulch had a better performance than black plastic mulch on specific fruit weight. Other findings by (Anzalone, Cirujeda et al. 2010) reported that the variable specific fruit weight was not affected by any mulch treatment.

Table 10 Specific fruit weight (g.frt-1) influenced by different mulching techniques

	Specific fruit weight/ (g.frt-^{1})						
	13WAT[1]	14WAT	15WAT	16WAT	17WAT	18WAT	19WAT
Treatments (T)							
Plastic	4.08	3.64 ab	2.89 ab	2.74	2.90	2.60	2.75
Garlic	4.51	3.83 ab	2.88 ab	2.95	3.07	2.76	2.88
Oat	4.58	4.25 a	3.21 a	3.02	3.06	2.86	3.01
Garlic + C	4.51	3.84 ab	3.16 a	3.04	3.20	2.83	2.91
Oat +C	4.27	3.68 ab	2.91 ab	2.72	2.85	2.39	2.69
No mulch	4.53	3.81 ab	2.96 ab	2.93	3.00	2.59	2.69
No mulch + C	4.02	3.37 b	2.59 b	2.72	2.70	2.59	2.72
Significance[2]	Ns	*	*	ns	ns	ns	ns

1 WAT = weeks after transplanting.
2 *, ** and *** refer to *P* values < 0.05, < 0.01 and < 0.001, respectively; ns = not significant.

4.4. Fruit quality

Fruit quality measurements were recorded weekly for fruit size and brix degrees. The complete data collected is shown In Appendix F.

4.4.1. Fruit size

Fruit size was calculated as volume (cm^3) of the fruit by measuring fruit height (H) and the radius square (r^2) of the fruit. Assuming that volume is = 4/3 Pi* (fruit radius)^2 * fruit height (Fieten 2012). Measurements were taken for representative fruits for all treatments between 11 to 19WAT. The results, as shown in Table 11, showed significant difference in fruit size between treatments on 11, 12, 13, 15, 16, 17 and 19 WAT. Only at 14 and 18WAT there was no significance difference between treatments.

The no mulch treatment had significantly larger fruit size at 11WAT (table 10). During this week the highest mean fruit size area of 12.4 cm^3 was recorded for the No mulch treatment. During this week all the treatments reach the highest mean values for fruit size. The Oat mulch treatment had significantly larger fruits at 12, 15 and 19WAT. The garlic mulch had the highest significantly higher fruits at 13 and 16WAT. Garlic mulch + C had significantly larger fruits only at 17WAT. The non-mulched treatment receiving extra composted tended to have the smallest fruits at 11, 12, 13, 15,16, 17 and 19 WAT.

Related findings to the one obtained during the 17WAT are reported by (Roe, Stoffella et al. 1997)who found an increase in fruit size when compost was used as a soil amendment. Other similar findings during 12, 13, 15, 16 and 17WAT were reported by (Monks, Monks et al. 1997)who observed an increased in fruit size when using organic mulch compared to black plastic mulch, during a dry experimental year. Results differ with the findings obtained by (Anzalone, Cirujeda et al. 2010)who observed a higher tomato fruit size with plastic mulch compared to organic mulch.

Table 11 Fruit size (cm^3) as affected by different mulching techniques.

	Fruit size (volume in cm3)								
	11WAT[1]	12WAT	13WAT	14WAT	15WAT	16WAT	17WAT	18WAT	19WAT
Treatments (T)									
Plastic	10.4 b	8.9 bcd	7.8 ab	7.1	5.9 ab	5.9 ab	5.7 ab	5.2	5.6 ab
Garlic	10.8 ab	10.2 abc	9.1 a	7.3	6.0 ab	6.7 a	6.0 ab	5.5	6.3 ab
Oat	10.4 ab	10.9 a	8.8 a	8.2	7.0 a	6.5 ab	6.5 a	5.4	6.4 a
Garlic + C	10.7 ab	8.8 cd	8.6 a	7.8	6.9 a	6.4 ab	6.7 a	5.9	6.2 ab
Oat +C	11.5 ab	10.0 abc	8.2 ab	7.4	6.4 ab	5.9 ab	5.9 ab	5.2	5.5 ab
No mulch	12.4 a	10.5 ab	8.5 a	7.4	6.3 ab	5.9 ab	5.6 ab	5.2	5.2 ab
No mulch + C	10.3 b	8.2 d	6.9 b	6.6	5.5 b	5.3 b	5.1 b	5.1	5.0 b
Significance[2]	**	***	**	ns	**	*	**	ns	**

1 WAT = weeks after transplanting.
2 *, ** and *** refer to *P* values < 0.05, < 0.01 and < 0.001, respectively; ns = not significant.

4.4.2. Brix degrees

Values for Brix degrees were measured at two stages of maturity (4 and 5). All treatments were measured between 15 and 20WAT at weekly intervals. At maturity stage 5, values were not significant and data is not shown. Results at maturity stage 4 are shown in Table 12. However, there was only a significant difference in brix degrees at 19WAT. Plastic and Oat where significantly higher compared to the rest of the treatments. The rest of the season there were no significance difference among treatments.

Based on reports in the literature, (Anzalone 2008)also reported that there was no significance difference among any types of mulch on brix degrees and similar findings were documented by (Moreno, Moreno et al. 2011).

Table 12 Effects of different mulching treatments on tomatoes, at maturity stage 4.

	Brix (°Bx)					
	15WAT[1]	16WAT	17WAT	18WAT	19WAT	20WAT
Treatments (T) at maturity stage 4						
Plastic	7.13	6.66	6.80	7.13	7.00 a	7.13
Garlic	5.73	6.80	7.00	6.06	5.13 b	6.06
Oat	6.40	6.46	7.20	6.26	7.00 a	6.26
Garlic + C	6.40	7.40	6.80	6.26	6.46 ab	6.26
Oat +C	6.53	6.60	7.13	5.93	5.66 ab	5.93
No mulch	6.60	6.53	6.60	6.93	5.06 b	6.93
No mulch + C	6.33	6.70	7.20	6.40	6.66 ab	6.40
Significance[2]	ns	ns	ns	ns	*	ns

1 WAT = weeks after transplanting.

2 *, ** and *** refer to *P* values < 0.05, < 0.01 and < 0.001, respectively; ns = not significant.

5. Water Use Efficiency

Values for water use efficiency (WUE) were not significant different from each other. The results obtained for water use efficiency per treatment are shown in Table 13. Table 12 shows that the highest water use efficiency was obtained with the use of Plastic mulch while the lowest values occurred with the use of Garlic straw but differences between treatments where not significant.

Related finding to the ones obtained on water use efficiency are reported by (Biswas, Akanda et al. 2015) who found that all mulches and unmulched treatments perform similar on WUE. In findings reported by (Mukherjee, Sarkar et al. 2012), use of plastic mulch resulted in higher WUE than organic mulch, due to the efficient weed control that it provides, together with the efficient use of water and nutrients.

Table 13 Water use efficiency (expressed as kg fresh fruit produced per m^3 of water applied) as affected by mulching treatments

	WUE (kg fruit m^{-3})
Treatment	
Plastic	9.14
Garlic	7.24
Oat	8.18
Garlic + C	8.64
Oat +C	7.74
No mulch	7.34
No mulch +C	8.05
Significance[2]	ns

1 WUE= water use efficiency.

2 *, ** and *** refer to *P* values < 0.05, < 0.01 and < 0.001, respectively; ns = not significant.

6. Conclusion

Plastic mulch together with Garlic straw with extra compost treatment appeared to perform best in terms of overall plant growth parameters. Use of plastic mulch resulted in significantly higher growth in terms of plant height, canopy density and canopy volume while Garlic straw with extra compost showed only significance differences in terms of plant height and canopy density.

In terms of overall crop yield measurements, plastic mulch together with oat mulch treatment had the best performance between treatments. Plastic mulch treatment was significantly higher at 13WAT and had the higher yields during the whole growing season. For specific fruit weight, the oat mulch treatment had a better performance and had significantly larger fruits at 14 and 15WAT.

Regarding fruit quality parameters, fruit size tended to decrease as the harvesting season progressed and there were no consistent differences among treatments across the growing season. For brix degrees plastic and oat showed a significant difference only for one week but there was no difference between both means, the rest of the time.

In terms of initial hypotheses, the hypothesis "tomato yields will be higher with organic mulch when compared to plastic on hot regions" was not confirm since the use of plastic mulch, especially during initial growth appeared to enhance overall crop growth. Moreover, when compared to organic mulches this treatment also had a higher cumulative yield of 43.6 t/ha which represents a difference of 5% with the garlic straw and extra compost treatment which had the second best cumulative yield.

The hypothesis "Straw mulch will increase soil organic matter content and will also ameliorated plant stress related to high temperature and low soil moisture more effectively compared to the use of plastic mulch" was partly confirmed. Although SOM values at the end of the growing season were not determined, based on tensiometers and soil moisture sensors it was evident that this treatment had higher soil moisture content values compared to the plastic mulch treatment.

The hypothesis "Increased organic matter addition are positively correlated with high water retention capacity" was confirmed as the data presented in **Error! Reference source not found.** nd **Error! Reference source not found.**, shows that the used of high compost combined with organic mulch, performs better in terms of sustaining high soil moisture values compared to the use of plastic mulch.

The hypothesis "Monitoring soil moisture tension or soil moisture content helps to identify problems in irrigation water management that might affect crop yield or water use" was confirmed. This due to the reason that if you have the right tool measurements (soil moisture sensors, tensiometer), and you know the soil profile, your soil irrigation threshold and monitor the soil daily you can help prevent problems that might affect yields like shown on **Error! eference source not found.** and **Error! Reference source not found.**, where 3 peaks where shown and visual observations confirmed problems of crop water stress.

The hypothesis “There is a clear correlation between cumulative water use and yields “ can’t be confirmed due to the reason that all treatments received the same amount of water. This was related to trials being conducted in a commercial operation with a single irrigation manifold and this situation could not be modified.

7. Recommendations for future research

The use of mulch Is really important in organic agriculture due to the reason that it protects the soil from radiation and soil degradation, minimize crop growth reduction due to weeds and increases soil water retention compared to bare soil. The use of organic mulch as shown in the results can be an option for Del Cabo farm as in addition to providing short-term benefits it may also enhance overall soil quality in the longt run. However, on a commercial scale the straw mulch requires more labor for applying and there were also some practical issues that need to be resolved as it tended to blow away. May be the use of in situ cultivated live mulches could be a viable alternative. Use of organic mulches may be cost effective since it can increase SOM but may also be more compatible with organic values since it is a local and renewable resource rather than a fossil-fuel based external input.

It is therefore recommended that del Cabo as part of future research, evaluates the performance of other organic mulch, like for example the use crop residues from previously grown crops on the farm or the evaluation of the used of cover crops as mulch like the hairy vetch that have the ability to suppress weeds and increase yields (Campiglia, Mancinelli et al. 2010), also organic mulch could increase the harvesting period when compared to plastic.

I recommended also the evaluation of the use of bioegradable plastic mulch due to the reason that it can provide the same functions as the traditional plastic mulch, while it causes less heat load of the soil which can be a benefit for hot regions like in Baja California, also it doesn't need to be removed from the soil and it doesn't contaminate the environment (Moreno and Moreno 2008).It is also recommended to also look more carefully at irrigation timing and application rates, based on actual crop demand. In the current experiment, the irrigation rate could not be changed and it may well be that further improvements in WUE may be accomplished by more carefully looking at the daily water balance and improved integration of soil moisture sensing equipment during the scheduling of irrigation events as was done in other production regions such as Florida.

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9. Appendices

Appendix A.

Appendix A. 1 Physical and biochemical soil parameters

Laboratorio Agrícola: Análisis Químicos, Físicos, Microbiológicos
Fitopatológicos, Residuos y Asesoría Para Certificación.
Ensenada y San Quintín, B. C.

Análisis de Agua, Suelo, Follaje, Fruto y Fertilizante.

Reporte de Resultados de Análisis de SUELOS AGRÍCOLAS

Solicitante: Agroproductos del Cabo, S. A de C. V.	**Reporte No. : 14/s114.**
Dirección: Carr. Transpeninsular Km. 125.5, Maneadero Parte Alta.	Fecha: 21 de Julio del 2014.
Población/tel/fax: Ensenada B.C.	Muestra Recibida: 15/*vii*/'14.

Muestras de Suelo Agrícola (1 de 1) para cultivo de **Tomate**, *Lycopersicon esculentum*
Identificación y Procedencia: Muestra No.1, **«OAP, LOTE 55, N07».**
At'n: Ing. Verónica Márquez.

(1) Salinidad y Toxicidad por Iones Específicos en Extracto de Saturación, ES, @ 25 °C

Identificación: Clave, Procedencia y/o No. de la(s) Muestra(s):	Código de Laboratorio: 140715s114. « OAP, LOTE 55, N07»	Valores Deseables (**Guía**) para:
Parámetros ↓ Analizados	Muestra No. 1	Tomate
% Saturación	60.8	(15) 20 a 50 (65)
pH	6.60	5.5 a 7.5
Conductividad Eléctrica, dS/m	***1.03***	2.5 a 3.5
Sales Solubles Totales, ppm	***659***	1,600 a 2,240
Sodio, Na, me/L	4.79	-
Calcio, Ca, me/L	3.89	-
Magnesio, Mg, me/L	1.49	-
Carbonatos, $CO_3^{=}$, me/L	0.00	0.0
Bicarbonatos, HCO_3^-, me/L	4.50	< 3.0
Cloruros, Cl^-, me/L	5.30	< 40
Relación de Adsorción de Na, **RAS**	2.90	< 6 a 12 (15 máx)
Riesgo por Sodicidad:	Nulo	Nulo a Bajo

(2) Resultados de Análisis de Fertilidad; Macronutrientes en ppm.

Nitrógeno de Nitratos, $N\text{-}NO_3^-$	17.2	> 20
Fósforo, $P\text{-}PO_4^{3-}$	***6.34***	(10) 15 a 25 (35)
Sodio, Na_{int}	253	-
Potasio, K_{int}	200	(100) 250 a 420 (700)
Calcio, Ca_{int}	***310***	1,000 a 2,000
Magnesio, Mg_{int}	112	> 100
Materia Orgánica, M. O., %	***1.7***	> 1.8
CaO, *Cal Libre*	(+)	Nulo(-) a Bajo(+)

(3) Resultados de Análisis de *Nutrientes Menores; Micronutrientes en ppm.*

Fierro, Fe	15.0	> 5.0
Zinc, Zn	3.0	> 1.0
Manganeso, Mn	2.4	> 1.0
Cobre, Cu	0.7	> 0.2

Los Símbolos < y > significan *Menor Que* y *Mayor Que*, respectivamente
Los resultados analíticos aquí reportados son específicos para la muestra recibida en el laboratorio y son para uso exclusivo y confidencial del solicitante

Para cualquier aclaración con respecto a estos resultados, favor de llamar a mi celular (646) 171-6454, o dejarme recado en el teléfono (646) 175-7883 de lunes a viernes de 9:00am a 2:00pm.
Sin más por el momento, reciban un afectuoso saludo.
Atentamente

Q. José Luis Castañeda Jiménez
Cédula Profesional 1535378

Ave. Moctezuma No. 1705. Ensenada, B. C. Zona Centro México 22800
Red: www.agroambiental.com.mx / Correo-e: jlcastanedaj@prodigy.net.mx / Tel/Cel: (646) 175-7883 / 171-6306

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(4) Resultados de Textura.

% Arena	69.3
% Limo	17.8
%Arcilla	12.9
Textura:	Franco Arenoso

Los Símbolos < y > significan *Menor Que* y *Mayor Que*, respectivamente

Los resultados analíticos aquí reportados son específicos para la muestra recibida en el laboratorio y son para uso exclusivo y confidencial del solicitante

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Cédula Profesional 1535378

Appendix B.

Appendix B.1 Foliar analysis of the macro and micronutrients of oat.

Laboratorio Agrícola: Análisis Químicos, Físicos, Microbiológicos Fitopatológicos, Residuos y Asesoría Para Certificación.

Ensenada y San Quintín, B. C.

Análisis de Agua, Suelo, Follaje, Fruto y Fertilizante.

Reporte de Resultados de ANÁLISIS FOLIARES

Solicitante Agroproductos del Cabo, S. A de C. V.	**Reporte No. : 14/f078.**
Dirección: Carr. Transpeninsular Km. 125.5, Maneadero Parte Alta.	**Fecha:** 24 de Julio del 2014.
Población/tel./fax Ensenada, B. C.	**Muestra Recibida:** 15/*vii*/'14.

Muestra: Una (1) Muestra foliar (1de 1) de **Avena**,
Identificación y Procedencia: Muestra No. 1, Ojos Negros ***«Muestra de Tejido»***.

Etapa de Desarrollo: ***«No estipulado»***

At'n: Ing. Verónica Márquez

MACRONUTRIENTES expresados en %; *micronutrientes* y Iones Tóxicos en mg*kg^{-1} (ppm).

Código y Zona(s) de Procedencia de la(s) Muestra(s):	Código de Laboratorio: 140715f078. «Muestra de Tejido»	Valores Adecuados (Guía) para Avena	
Nutrientes ↓ Analizados	*Muestra No 1*	*Deficiente*	SUFICIENTE
Nitrógeno N_{Total}%	***1.75***	< 2.0	3.00-5.00
Fósforo, P_{Total}, %	0.89	< 0.15	0.25-0.70
Potasio, K_{Total}, %	3.70	< 1.0	2.00-3.50
Calcio, Ca, %	***0.48***	< 0.50	0.80-3.00
Magnesio, Mg, %	***0.10***	< 0.15	0.25-1.00
Fierro, Fe, ppm	***23***	< 30	30-250
Zinc, Zn, ppm	***14***	< 20	20-70
Manganeso, Mn, ppm	***20***	< 25	25-100
Cobre, Cu, ppm	***2***	< 4	4-30
Boro, B, ppm	***34***	< 20	20-80
Iones Tóxicos		**Valores Excesivos**	
Sodio, Na^+, ppm	3,800	> 10,000 (1.0 %)	
Cloruros, Cl^-, ppm	***26,942***	> 5,000 (0.5 %)	

Los Símbolos < y > significan *Menor Que* y *Mayor Que*, respectivamente.

Los resultados analíticos aquí reportados son específicos para la muestra recibida en el laboratorio y son para uso exclusivo y confidencial del solicitante.

Para cualquier aclaración con respecto a estos resultados, favor de llamar a mi celular (646) 171-6454, o dejarme recado en el teléfono (646) 175-7883 de lunes a viernes de 9:00am a 2:00pm.

Sin más por el momento, reciban un afectuoso saludo.

Atentamente

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Appendix B.2 foliar analysis of the macro and micronutrients of garlic

Laboratorio Agrícola: Análisis Químicos, Físicos, Microbiológicos Fitopatológicos, Residuos y Asesoría Para Certificación.

Ensenada y San Quintín, B. C.

Análisis de Agua, Suelo, Follaje, Fruto y Fertilizante.

Reporte de Resultados de ANÁLISIS FOLIARES

Solicitante Agroproductos del Cabo, S. A de C. V.	**Reporte No. : 14/f077.**
Dirección: Carr. Transpeninsular Km. 125.5, Maneadero Parte Alta.	**Fecha:** 24 de Julio del 2014.
Población/tel./fax Ensenada, B. C.	**Muestra Recibida:** 15/*vii*/'14.

Muestra: Una (1) Muestra foliar (1de 1) de **Ajo**, *Allium sativus*.
Identificación y Procedencia: Muestra No. 1, Ojos Negros ***«Muestra de Tejido»***.

Etapa de Desarrollo: «No estipulada»

At'n: Ing. Verónica Márquez

MACRONUTRIENTES expresados en % ; *micronutrientes* y Iones Tóxicos en mg* kg^{-1} (ppm).

Código y Zona(s) de Procedencia de la(s) Muestra(s):	Código de Laboratorio: 140715f077. «Muestra de Tejido»	Valores Adecuados (Guía) para Ajo	
Nutrientes ↓ Analizados	*Muestra No 1*	*Deficiente*	SUFICIENTE
Nitrógeno N_{Total}%	***1.47***	*<4.00*	5.00
Fósforo, P_{Total}, %	*0.66*	*<0.20*	0.30
Potasio, K_{Total}, %	*5.00*	*<3.00*	4.00
Calcio, Ca, %	***0.58***	*<0.70*	0.80
Magnesio, Mg, %	0.18	*<0.14*	0.15
Fierro, Fe, ppm	***28***	*<60*	100 a 300
Zinc, Zn, ppm	***5***	*<10*	25 a 40
Manganeso, Mn, ppm	***15***	*<25*	50 a 200
Cobre, Cu, ppm	***3***	*<10*	15 a 30
Boro, B, ppm	35	*<20*	25 a 80
Iones Tóxicos		**Valores Excesivos**	
Sodio, Na^+, ppm	610	**> 10,000 (1.00 %)**	
Cloruros, Cl^-, ppm	***12,053***	**> 5,000 (0.50 %)**	

Los Símbolos < y > significan ***Menor Que*** y ***Mayor Que***, respectivamente

Los resultados analíticos aquí reportados son específicos para la muestra recibida en el laboratorio y son para uso exclusivo y confidencial del solicitante

Para cualquier aclaración con respecto a estos resultados, favor de llamar a mi celular (646) 171-6454, o dejarme recado en el teléfono (646) 175-7883 de lunes a viernes de 9:00am a 2:00pm.
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Appendix C.

Appendix C.1 Irrigation water applied

Date	Irrigation per event	Cumulative irrigation	
	lt/ha	Cumulative lt/ha	Cumulative mm/crop
6/17/14	37312.5	37312.5	3.73125
6/19/14	22465	59777.5	5.97775
6/21/14	25850	85627.5	8.56275
6/24/14	23465	109092.5	10.90925
6/25/14	18241.25	127333.75	12.733375
6/28/14	21080	148413.75	14.841375
6/30/04	31620	180033.75	18.003375
7/2/14	40442	220475.75	22.047575
7/4/14	19528.5	240004.25	24.000425
7/7/14	48752	288756.25	28.875625
7/8/14	30885.5	319641.75	31.964175
7/10/14	29085	348726.75	34.872675
7/11/14	24237.5	372964.25	37.296425
7/12/14	40165	413129.25	41.312925
7/15/14	69250	482379.25	48.237925
7/16/14	18974.5	501353.75	50.135375
7/18/14	25622.5	526976.25	52.697625
7/19/14	24653	551629.25	55.162925

7/21/14	24583.75	576213	57.6213
7/22/14	72020	648233	64.8233
7/24/14	79637.5	727870.5	72.78705
7/26/14	92102.5	819973	81.9973
7/28/14	66480	886453	88.6453
7/30/14	82407.5	968860.5	96.88605
8/2/14	24237.5	993098	99.3098
8/4/14	105952.5	1099050.5	109.90505
8/6/14	63710	1162760.5	116.27605
8/7/14	27007.5	1189768	118.9768
8/9/14	42865.75	1232633.75	123.263375
8/10/14	27700	1260333.75	126.033375
8/11/14	124234.5	1384568.25	138.456825
8/12/14	23545	1408113.25	140.811325
8/13/14	63710	1471823.25	147.182325
8/14/14	109761.25	1581584.5	158.15845
8/16/14	57823.75	1639408.25	163.940825
8/17/14	23545	1662953.25	166.295325
8/18/14	101382	1764335.25	176.433525
8/19/14	21467.5	1785802.75	178.580275
8/20/14	107683.75	1893486.5	189.34865
8/21/14	23545	1917031.5	191.70315
8/22/14	106645	2023676.5	202.36765
8/23/14	26315	2049991.5	204.99915
8/24/14	23545	2073536.5	207.35365
8/25/14	121880	2195416.5	219.54165
8/26/14	76175	2271591.5	227.15915
8/27/14	22852.5	2294444	229.4444

8/28/14	115301.25	2409745.25	240.974525
8/29/14	120495	2530240.25	253.024025
8/30/14	21467.5	2551707.75	255.170775
8/31/14	54707.5	2606415.25	260.641525
9/1/14	67588	2674003.25	267.400325
9/2/14	20775	2694778.25	269.477825
9/3/14	48475	2743253.25	274.325325
9/4/14	70635	2813888.25	281.388825
9/5/14	29085	2842973.25	284.297325
9/6/14	76175	2919148.25	291.914825
9/7/14	20775	2939923.25	293.992325
9/8/14	112185	3052108.25	305.210825
9/9/14	24237.5	3076345.75	307.634575
9/10/14	22160	3098505.75	309.850575
9/11/14	70635	3169140.75	316.914075
9/12/14	36702.5	3205843.25	320.584325
9/13/14	26315	3232158.25	323.215825
9/14/14	21467.5	3253625.75	325.362575
15-Sep	117032.5	3370658.25	337.065825
9/17/14	52630	3423288.25	342.328825
9/18/14	49167.5	3472455.75	347.245575
9/19/14	50552.5	3523008.25	352.300825
9/20/14	55400	3578408.25	357.840825
9/21/14	22160	3600568.25	360.056825
9/23/14	76175	3676743.25	367.674325
9/24/14	90025	3766768.25	376.676825
9/25/14	24930	3791698.25	379.169825
9/26/14	106645	3898343.25	389.834325

9/30/14	104567.5	4002910.75	400.291075
10/2/14	101105	4104015.75	410.401575
10/3/14	42935	4146950.75	414.695075
10/5/14	70635	4217585.75	421.758575
10/8/14	101105	4318690.75	431.869075
10/10/14	42935	4361625.75	436.162575
10/11/14	38780	4400405.75	440.040575
10/14/14	81715	4482120.75	448.212075
10/16/14	25622.5	4507743.25	450.774325
10/18/14	23545	4531288.25	453.128825
10/19/14	24237.5	4555525.75	455.552575
10/20/14	105260	4660785.75	**466.078575**

Appendix C.2 Soil moisture sensor readings

Treatment	VWC (m^3/m^3)		
	T1 (Plastic)	T2 (Straw)	T3 (Straw + C)
Date			
7/10/14	0.231	0.363	0.45
7/11/14	0.233	0.343	0.443
7/12/14	0.23	0.343	0.429
7/13/14	0.234	0.351	0.434
7/14/14	0.228	0.328	0.419
7/15/14	0.226	0.341	0.394
7/16/14	0.222	0.318	0.367
7/17/14	0.221	0.305	0.348
7/18/14	0.216	0.283	0.308
7/19/14	0.218	0.281	0.299
7/21/14	0.211	0.263	0.258
7/22/14	0.207	0.246	0.244
7/23/14	0.21	0.263	0.253
7/24/14	0.21	0.236	0.235
7/25/14	0.22	0.295	0.256
7/26/14	0.243	0.315	0.271
7/28/14	0.216	0.207	0.225
7/29/14	0.211	0.23	0.23
7/30/14	0.222	0.243	0.24
7/31/14	0.199	0.2	0.201
8/1/14	0.183	0.176	0.205
8/2/14	0.192	0.194	0.211
8/4/14	0.201	0.212	0.217
8/5/14	0.208	0.256	0.224
8/6/14	0.189	0.179	0.202
8/7/14	0.202	0.221	0.216
8/8/14	0.195	0.192	0.205
8/9/14	0.184	0.185	0.2
8/11/14	0.177	0.171	0.19
8/12/14	0.212	0.25	0.228
8/13/14	0.194	0.194	0.21
8/14/14	0.201	0.231	0.218
8/15/14	0.213	0.253	0.23

8/16/14	0.219	0.293	0.24
8/18/14	0.224	0.302	0.239
8/19/14	0.2	0.223	0.214
8/20/14	0.219	0.322	0.234
8/21/14	0.203	0.239	0.214
8/22/14	0.184	0.196	0.198
8/24/14	0.187	0.211	0.199
8/25/14	0.2	0.315	0.223
8/26/14	0.196	0.236	0.206
8/27/14	0.206	0.264	0.218
8/28/14	0.219	0.348	0.227
8/29/14	0.199	0.244	0.206
8/30/14	0.208	0.275	0.214
8/31/14	0.191	0.271	0.2
9/1/14	0.195	0.241	0.201
9/2/14	0.202	0.257	0.209
9/3/14	0.188	0.228	0.196
9/4/14	0.195	0.248	0.206
9/6/14	0.212	0.31	0.22
9/8/14	0.192	0.233	0.199
9/11/14	0.207	0.295	0.218
9/12/14	0.208	0.321	0.222
9/15/14	0.198	0.293	0.223
9/17/14	0.222	0.354	0.229
9/18/14	0.214	0.326	0.225
9/19/14	0.215	0.339	0.232
9/23/14	0.187	0.236	0.198
9/25/14	0.209	0.284	0.217
9/26/14	0.211	0.287	0.218
9/30/14	0.208	0.335	0.222
10/2/14	0.195	0.254	0.203
10/3/14	0.214	0.328	0.221
10/5/14	0.207	0.293	0.214
10/8/14	0.191	0.243	0.198
10/10/14	0.199	0.258	0.204
10/11/14	0.2	0.265	0.208
10/14/14	0.193	0.244	0.2
10/16/14	0.202	0.269	0.208
10/20/14	0.193	0.23	0.199

Appendix C.3 Soil moisture tension readings

Treatment	Tensiometer readings (Cbar)		
	T1 (Plastic)	T2 (Straw)	T3 (Straw + C)
Date			
7/10/14	10	12	7
7/11/14	10	10	9
7/12/14	10	9	9
7/13/14	10	10	10
7/14/14	12	10	12
7/15/14	12	9	9
7/16/14	12	10	14
7/17/14	12	10	16
7/18/14	16	16	28
7/19/14	18	20	28
7/21/14	20	30	48
7/22/14	28	48	68
7/23/14	20	16	8
7/24/14	32	40	48
7/25/14	20	14	10
7/26/14	6	12	4
7/28/14	20	26	40
7/29/14	16	14	10
7/30/14	12	12	8
7/31/14	22	22	22
8/1/14	52	72	80
8/2/14	23	19	14
8/4/14	30	14	10
8/5/14	12	12	6
8/6/14	22	18	28
8/7/14	14	14	10
8/8/14	19	19	25
8/9/14	50	20	22
8/11/14	74	64	80
8/12/14	9	14	8
8/13/14	19	19	13
8/14/14	20	14	10
8/15/14	8	12	8
8/16/14	6	10	2
8/18/14	6	14	2

8/19/14	10	14	10
8/20/14	6	12	4
8/21/14	9	12	8
8/22/14	12	20	30
8/24/14	11	15	25
8/25/14	10	10	20
8/26/14	10	14	10
8/27/14	8	12	8
8/28/14	6	12	4
8/29/14	10	12	10
8/30/14	9	12	8
8/31/14	22	14	10
9/1/14	20	12	12
9/2/14	10	8	12
9/3/14	28	12	22
9/4/14	18	12	10
9/6/14	6	12	4
9/8/14	22	11	8
9/11/14	12	10	2
9/12/14	10	10	7
9/15/14	12	12	6
9/17/14	10	10	4
9/18/14	10	10	4
9/19/14	12	12	6
9/23/14	20	12	12
9/25/14	8	10	7
9/26/14	10	10	7
9/30/14	10	8	4
10/2/14	12	10	8
10/3/14	9	8	6
10/5/14	12	10	8
10/8/14	10	9	4
10/10/14	8	8	10
10/11/14	8	6	4
10/14/14	11	10	12
10/16/14	4	10	4
10/20/14	18	11	8

Appendix D

Appendix D.1 Plant height

Treatment	Plant height (cm)											
	2 WAT	3 WAT	4 WAT	5 WAT	6 WAT	7 WAT	8 WAT	9 WAT	10 WAT	11 WAT	12 WAT	13 WAT
Plastic	15.83	28.00	50.33	81.00	100.67	124.33	139.00	148.33	156.67	161.33	168.00	176.67
Plastic	18.33	37.33	63.33	85.00	107.00	126.33	135.67	146.00	153.00	158.67	164.67	168.33
Plastic	21.33	40.00	68.00	92.00	112.00	125.00	138.33	147.00	156.33	160.67	165.33	175.00
Plastic	23.00	37.33	60.00	84.00	103.00	125.00	150.33	147.67	151.00	149.00	157.33	160.67
Plastic	20.67	33.67	61.67	84.33	104.33	124.00	138.67	148.33	157.67	160.33	161.67	167.33
Plastic	22.33	34.33	61.33	87.67	105.00	131.00	138.33	158.00	166.00	167.67	173.33	175.00
Plastic	18.33	33.67	62.00	86.00	112.00	123.67	137.00	144.00	150.67	155.33	162.67	158.00
Plastic	16.67	28.33	57.00	81.33	100.67	120.33	137.67	145.00	152.67	156.00	163.17	167.67
Plastic	20.00	35.33	65.67	80.67	105.67	133.00	149.00	165.33	173.33	179.33	169.33	184.00
Garlic	19.00	30.33	54.00	70.67	97.33	116.33	133.67	148.33	164.33	174.33	172.33	182.00
Garlic	19.00	33.33	58.67	74.67	97.67	113.33	127.33	138.33	143.33	147.67	155.00	163.00
Garlic	18.33	32.00	56.00	80.33	103.00	118.67	127.33	138.00	144.67	150.33	158.67	167.33
Garlic	23.00	35.00	57.33	75.67	95.00	111.33	123.67	133.33	143.67	149.67	154.33	158.33
Garlic	20.00	31.00	55.67	79.00	96.33	119.33	130.33	145.67	152.67	161.67	167.67	161.33
Garlic	19.67	34.33	57.33	79.67	99.33	118.00	135.00	143.00	154.67	157.33	164.00	172.00
Garlic	17.67	32.67	60.00	74.33	95.33	110.00	132.33	139.67	153.33	156.67	163.33	165.33
Garlic	21.00	37.33	62.67	77.33	96.67	114.00	132.00	144.33	153.33	157.67	161.33	170.00
Garlic	20.00	34.00	56.33	71.00	88.67	106.33	128.00	136.67	144.00	148.00	161.33	159.67
Oat	20.33	29.33	51.00	66.67	82.67	107.67	124.33	135.00	141.33	98.00	149.00	162.00
Oat	18.33	29.00	56.33	73.00	105.33	122.67	132.33	148.67	152.33	158.33	165.33	164.00
Oat	19.67	33.33	58.33	78.67	100.67	124.33	140.33	161.00	166.67	168.33	166.33	174.33
Oat	21.00	34.00	53.33	76.67	94.67	109.00	127.00	141.33	147.67	155.00	165.33	170.67
Oat	21.00	35.67	58.00	79.33	98.67	116.33	126.00	141.00	146.00	149.67	154.00	158.67

Oat	19.67	32.00	54.33	71.67	85.00	96.00	128.33	120.67	137.33	143.67	147.00	155.33
Oat	19.33	28.00	48.33	71.33	93.33	106.67	123.67	134.33	141.33	143.33	157.17	150.33
Oat	19.67	31.33	56.33	65.33	88.33	110.67	128.00	136.00	141.33	149.00	159.67	167.33
Oat	23.33	34.67	64.67	73.33	90.33	115.67	138.67	154.00	163.33	173.00	156.67	178.33
Garlic + C[1]	16.67	33.00	57.67	70.67	91.67	114.00	128.33	146.00	155.67	161.33	172.67	172.00
Garlic + C	19.00	30.67	53.00	75.33	96.00	112.67	132.33	145.67	154.00	160.00	165.33	168.33
Garlic + C	17.33	29.33	51.67	66.67	92.00	112.67	126.67	143.00	155.00	161.67	175.00	182.67
Garlic + C	22.00	33.33	60.00	73.33	85.33	105.33	134.00	146.33	157.67	161.00	167.00	178.33
Garlic + C	21.00	31.67	58.67	76.00	95.00	112.67	131.67	146.00	157.67	161.67	167.67	183.67
Garlic + C	19.00	31.00	55.67	76.33	99.67	116.67	97.33	143.67	150.00	157.33	161.67	164.33
Garlic + C	19.67	33.33	58.00	79.67	97.00	118.67	137.00	148.33	162.33	163.33	169.83	166.67
Garlic + C	19.00	33.00	62.00	83.00	100.67	120.00	140.00	148.00	150.00	150.00	166.50	164.67
Garlic + C	17.67	30.67	63.33	84.67	98.67	120.00	139.67	149.33	160.33	163.00	168.33	176.33
Oat + C	20.33	36.33	58.00	74.67	94.33	112.67	131.33	143.33	148.00	152.67	161.00	166.00
Oat + C	17.67	31.67	57.33	72.67	96.67	119.00	132.33	148.33	157.00	163.67	166.33	175.67
Oat + C	20.00	36.33	57.33	77.33	94.00	116.67	135.67	152.00	158.00	167.67	172.67	178.00
Oat + C	20.67	33.00	55.00	77.33	99.00	115.67	135.67	147.00	159.33	165.33	166.00	180.33
Oat + C	20.00	32.33	60.00	78.00	97.33	118.67	135.00	151.33	156.67	162.00	171.67	176.67
Oat + C	20.00	34.33	58.00	74.67	94.33	119.00	135.00	152.67	158.33	163.33	168.67	166.00
Oat + C	19.33	33.67	55.00	72.67	94.00	110.67	128.00	136.67	144.67	148.67	163.50	163.00
Oat + C	19.67	30.00	57.00	74.67	91.33	103.33	126.67	135.67	141.33	145.00	169.00	159.67
Oat + C	20.67	34.67	62.00	80.33	104.67	120.00	139.33	148.00	154.33	156.67	170.67	176.33

1 C= high compost.

Appendix D.2 Canopy density

	Canopy density (Scale 1-10)							
Treatment	6 WAT[1]	7 WAT	8 WAT	9 WAT	10 WAT	11 WAT	12 WAT	13 WAT
Plastic	5.00	6.00	6.00	7.67	6.67	7.00	7.33	7.00
Plastic	5.33	6.33	6.67	6.67	6.67	6.67	7.00	6.67
Plastic	7.00	7.33	8.00	7.67	7.67	7.33	7.00	7.00
Plastic	6.33	7.33	8.00	7.67	8.00	8.00	8.00	6.33
Plastic	6.33	7.33	7.00	7.00	7.67	7.67	7.67	7.67
Plastic	6.67	7.33	7.67	7.67	8.33	8.00	8.33	8.00
Plastic	7.00	7.67	8.33	7.33	7.00	7.33	7.67	6.67
Plastic	5.67	7.67	8.00	7.67	7.67	7.33	7.33	6.67
Plastic	5.33	7.00	7.67	7.67	7.67	7.00	7.67	7.00
Garlic	4.00	7.00	7.00	8.00	7.67	6.33	7.33	8.00
Garlic	4.33	5.67	6.00	6.67	7.00	7.67	7.00	7.00
Garlic	3.33	5.67	6.33	7.67	7.33	7.33	7.33	7.33
Garlic	4.33	6.33	6.67	6.33	6.33	7.67	7.00	6.33
Garlic	6.00	6.33	7.67	7.67	7.67	7.67	8.00	7.33
Garlic	6.33	7.00	8.00	7.67	7.67	8.00	8.00	7.67
Garlic	5.00	6.00	7.00	7.00	7.00	7.33	7.17	6.67
Garlic	6.00	6.33	7.00	7.33	7.67	7.67	7.50	7.00
Garlic	5.00	6.00	6.67	7.00	7.00	7.67	7.67	6.67
Oat	3.00	4.33	6.33	6.00	6.00	6.33	6.00	6.33
Oat	4.33	6.67	7.33	8.00	8.00	8.00	7.67	7.33

Oat	3.33	6.00	7.33	7.66	7.66	7.66	7.33	8.00
Oat	6.00	7.00	7.00	6.67	7.00	7.67	7.67	7.33
Oat	5.67	6.33	6.00	6.00	6.33	6.33	6.33	6.67
Oat	4.00	5.67	6.67	6.00	6.00	5.67	6.00	6.00
Oat	4.33	6.33	5.00	6.00	6.33	6.00	6.83	6.00
Oat	5.33	6.67	7.00	6.67	7.33	7.00	7.00	6.33
Oat	4.67	5.67	7.33	7.67	7.33	7.67	6.67	7.33
Garlic + C	5.00	6.33	7.33	7.33	7.33	8.00	8.67	7.67
Garlic + C	4.67	6.67	7.33	7.00	7.67	7.67	7.67	7.33
Garlic + C	5.33	6.67	6.67	7.00	8.00	7.67	8.00	8.33
Garlic + C	5.00	5.67	7.00	6.67	7.00	7.33	7.67	7.67
Garlic + C	4.33	6.67	7.00	7.00	7.33	7.33	7.00	7.00
Garlic + C	6.00	7.33	6.33	7.00	6.67	7.67	7.00	6.33
Garlic + C	6.00	7.00	8.33	7.33	7.33	8.00	8.17	8.00
Garlic + C	6.00	8.67	8.33	8.00	7.67	7.67	7.33	7.67
Garlic + C	5.67	7.33	8.00	8.00	8.00	8.33	7.50	8.33
Oat + C	4.67	7.00	6.67	7.00	7.33	7.67	7.33	6.33
Oat + C	4.67	5.67	7.67	7.67	8.00	8.33	8.33	7.00
Oat + C	5.33	6.67	7.00	7.67	7.33	7.67	8.00	7.00
Oat + C	5.00	6.00	7.33	6.33	6.67	7.33	6.67	6.67
Oat + C	5.67	7.00	7.33	7.67	7.67	7.67	7.67	7.00
Oat + C	5.67	7.00	7.67	7.00	7.33	7.67	7.33	7.00
Oat + C	6.33	7.33	8.00	7.67	7.00	7.33	7.00	7.00
Oat + C	4.00	6.67	6.67	6.00	5.67	6.33	8.00	6.00
Oat + C	6.00	7.67	7.67	7.33	8.00	7.67	7.67	7.33

Appendix D.3 Canopy volume

	Canopy volume (cm^3)		
Treatment	2 WAT	3 WAT	4 WAT
Plastic	1948.16	13468.04	66274.24
Plastic	4163.99	30439.86	112065.05
Plastic	6047.41	36284.44	116973.37
Plastic	6366.06	26506.25	86698.89
Plastic	5119.36	25245.91	109008.40
Plastic	4911.46	25492.28	93975.16
Plastic	3880.42	21156.37	102910.01
Plastic	2620.54	12743.65	100924.83
Plastic	4384.37	25024.64	114895.51
Garlic	2929.97	19627.87	85172.50
Garlic	3526.57	21972.25	79689.32
Garlic	3215.20	22641.49	83699.84
Garlic	6355.36	24316.39	85779.37
Garlic	4542.53	17650.99	72830.56
Garlic	5681.31	23687.52	71770.63
Garlic	3103.42	18018.72	71780.40
Garlic	6403.51	38098.67	90734.37
Garlic	4326.22	24962.07	79107.65
Oat	2780.88	14298.71	58540.07
Oat	2718.43	17695.99	80738.94
Oat	3519.94	25602.63	82462.31

Oat	4096.83	20551.30	69963.85
Oat	5982.22	31374.72	90554.11
Oat	3913.33	19091.20	60596.96
Oat	3273.66	12582.33	47845.85
Oat	3458.19	16702.05	93553.39
Oat	5641.53	24794.37	94457.40
Garlic + C	2421.87	17676.80	89570.94
Garlic + C	2706.80	14907.63	71653.06
Garlic + C	2854.38	17739.06	74978.84
Garlic + C	5696.54	24526.89	101736.00
Garlic + C	4689.07	17864.86	77246.79
Garlic + C	4385.01	18206.19	66648.05
Garlic + C	4588.04	25158.77	97670.28
Garlic + C	3911.04	22790.64	118718.75
Garlic + C	3205.13	18295.73	91843.26
Oat + C	4604.05	25530.06	96186.34
Oat + C	2619.57	16588.79	80011.85
Oat + C	3842.43	22405.35	76971.40
Oat + C	4041.41	20121.47	85358.57
Oat + C	5298.46	25071.45	95637.42
Oat + C	5219.38	24759.60	54804.63
Oat + C	3651.39	21354.09	87069.58
Oat + C	3508.50	18121.29	87501.33
Oat + C	5638.51	26423.14	106028.50

Appendix E

Appendix E.1 Crop weekly yield

	Weekly yields (tons/ha)								
Treatment	11 WAT	12 WAT	13 WAT	14 WAT	15 WAT	16 WAT	17 WAT	18 WAT	19 WAT
Plastic	0.63	7.96	11.66	9.23	3.98	3.77	5.29	2.80	2.72
Plastic	0.87	7.21	8.14	7.98	4.19	3.39	6.08	2.98	3.19
Plastic	0.22	7.99	9.90	7.42	1.92	2.06	4.79	2.79	3.36
Garlic	0.59	5.61	5.55	5.83	2.40	2.75	4.80	2.81	3.88
Garlic	0.33	4.21	5.37	4.00	5.48	2.91	4.70	2.89	3.32
Garlic	0.22	4.51	5.46	8.27	5.05	3.64	3.46	2.60	4.34
Oat	0.43	7.50	8.88	6.72	2.89	3.34	5.59	3.29	2.35
Oat	0.45	6.45	4.44	4.52	5.15	3.69	4.65	2.75	4.11
Oat	0.44	5.76	6.66	8.22	7.33	3.32	3.35	2.68	3.64
Garlic + C	0.47	8.27	7.40	11.52	6.13	5.16	9.44	4.51	2.80
Garlic + C	0.23	2.85	4.07	1.77	1.78	3.93	3.97	2.63	3.77
Garlic + C	0.22	5.43	5.74	14.44	5.97	2.08	3.98	3.04	3.62
Oat + C	0.56	7.56	6.29	9.34	2.90	2.39	3.75	2.12	2.52
Oat + C	0.59	5.48	5.92	8.89	3.03	3.97	4.90	2.97	3.77
Oat + C	0.17	6.44	6.11	9.26	3.92	2.23	3.09	1.64	2.41
No mulch	0.12	5.39	5.18	5.00	2.94	2.37	3.71	3.97	3.66
No mulch	0.43	5.87	5.92	4.62	3.54	2.68	4.79	2.15	3.73
No mulch	0.31	4.68	5.55	9.86	6.90	2.33	3.86	2.60	4.24
No mulch +C	0.76	6.47	8.07	6.75	3.10	2.21	5.48	4.72	4.03
No mulch +C	1.11	6.14	6.11	6.14	2.69	3.08	4.54	3.20	2.58

No mulch +C	0.87	6.60	7.09	12.14	3.60	2.08	2.54	2.32	2.69

Appendix E.2 Specific fruit weight

	Specific fruit weight (g.frt-^{1})						
Treatment	WAT13	WAT14	WAT15	WAT16	WAT17	WAT18	WAT19
Plastic	4.11	3.70	3.00	2.63	2.88	2.78	2.56
Plastic	4.23	3.90	3.00	2.97	3.09	2.61	2.91
Plastic	3.90	3.33	2.68	2.63	2.75	2.42	2.78
Garlic	4.69	3.66	2.83	3.13	3.06	2.94	2.94
Garlic	4.29	4.00	3.03	2.80	3.19	2.61	2.83
Garlic	4.55	3.85	2.80	2.94	2.97	2.73	2.88
Oat	4.92	4.23	3.33	3.30	3.45	3.13	3.19
Oat	4.35	4.05	3.37	3.13	3.06	3.03	3.13
Oat	4.48	4.48	2.94	2.65	2.68	2.44	2.73
Garlic + C	4.69	4.11	3.41	3.19	3.45	3.03	3.09
Garlic + C	4.00	3.41	3.09	2.97	3.19	2.88	2.97
Garlic + C	4.84	4.00	3.00	2.97	2.97	2.59	2.68
Oat + C	4.55	3.80	3.00	2.75	2.94	2.56	2.56
Oat + C	4.17	3.41	2.97	2.80	2.88	2.46	2.73
Oat + C	4.11	3.85	2.78	2.61	2.75	2.17	2.78
No mulch	5.00	3.53	3.23	3.23	3.13	2.70	2.86
No mulch	4.11	3.90	2.68	2.73	2.86	2.38	2.38
No mulch	4.48	4.00	2.97	2.83	3.03	2.70	2.83
No mulch +C	4.17	3.45	2.75	2.97	2.97	2.94	2.75
No mulch +C	3.61	3.06	2.54	2.52	2.63	2.38	2.83
No mulch +C	4.29	3.61	2.50	2.68	2.50	2.46	2.59

Appendix F

Appendix F.1 Fruit size

	Fruit size (cm^3)								
Treatment	11WAT	12WAT	13WAT	14WAT	15WAT	16WAT	17WAT	18WAT	19WAT
Plastic	6.50	12.57	8.70	8.09	6.65	7.46	5.19	4.98	4.32
Plastic	12.67	8.00	3.91	6.60	4.29	7.15	2.51	5.61	5.95
Plastic	11.78	9.09	10.98	5.27	9.12	3.94	7.27	2.95	2.99
Plastic	7.94	7.15	7.45	8.33	5.60	5.61	6.98	5.81	3.60
Plastic	8.50	7.91	4.09	8.54	6.78	6.90	3.55	7.52	4.47
Plastic	3.30	7.52	9.18	7.50	5.29	4.16	4.20	3.63	9.31
Plastic	10.35	9.23	6.02	5.91	6.41	7.06	5.78	4.07	4.81
Plastic	10.83	11.63	6.41	4.73	6.99	5.22	4.88	5.95	5.18
Plastic	13.83	8.68	6.46	4.62	6.75	6.73	6.29	8.95	4.79
Plastic	9.13	10.83	7.58	6.02	4.95	5.17	6.21	7.26	7.07
Plastic	13.34	7.46	13.00	5.95	3.79	3.08	6.72	6.56	6.49
Plastic	17.13	6.69	9.67	9.92	4.84	6.55	5.19	3.33	5.20
Plastic	15.99	10.29	4.86	5.18	4.75	6.09	3.96	8.58	9.80
Plastic	8.59	5.20	4.57	6.86	7.33	6.86	5.05	4.60	4.93
Plastic	9.35	12.43	6.51	9.35	5.02	7.73	4.53	5.55	8.71
Plastic	10.78	8.39	5.80	7.70	8.38	5.86	10.02	4.49	5.00
Plastic	6.83	8.99	5.97	7.42	6.51	6.88	6.40	4.65	4.96
Plastic	10.71	8.38	10.15	8.07	5.92	4.58	7.99	4.30	7.35
Plastic	9.64	6.50	5.31	11.69	5.54	7.79	4.41	6.22	5.18
Plastic	11.96	12.13	7.93	5.91	6.19	6.04	7.00	4.94	5.71

Plastic	9.52	9.84	12.98	7.10	5.79	4.35	5.55	6.89	6.23
Plastic	14.85	7.36	5.40	8.50	6.95	7.06	4.80	4.39	5.37
Plastic	13.78	9.70	10.51	7.73	5.72	5.36	3.96	5.36	6.40
Plastic	8.26	6.12	7.34	8.12	5.49	7.54	10.10	3.68	5.37
Plastic	8.92	10.02	7.41	8.36	4.85	6.50	5.03	6.72	5.60
Plastic	6.32	7.94	7.75	8.52	6.39	3.14	5.39	3.30	7.04
Plastic	8.48	9.13	7.50	5.04	5.53	4.96	7.59	5.67	5.72
Plastic	10.79	9.91	10.45	5.44	5.06	5.70	5.37	3.37	5.21
Plastic	11.63	7.54	11.14	4.22	4.05	4.91	4.89	3.86	2.33
Plastic	10.48	11.48	7.92	6.52	4.99	5.90	5.76	3.28	4.30
Garlic	8.54	13.04	12.83	12.11	4.03	7.46	9.43	5.31	6.12
Garlic	10.54	9.07	8.65	6.73	6.35	4.60	5.16	8.95	3.62
Garlic	13.30	9.66	7.56	11.93	6.87	7.06	5.27	5.50	6.15
Garlic	8.01	8.15	7.80	4.53	5.69	4.83	5.85	5.72	9.41
Garlic	12.55	10.17	8.30	6.03	5.23	7.58	9.78	5.94	8.00
Garlic	9.38	11.91	9.56	5.83	10.97	13.04	5.01	5.38	12.16
Garlic	8.18	9.17	8.89	7.30	5.37	3.70	5.49	4.65	6.69
Garlic	7.77	6.65	8.32	7.62	5.53	6.19	5.76	4.04	11.38
Garlic	9.53	10.57	9.73	8.24	3.96	12.03	7.00	6.45	5.59
Garlic	12.36	12.53	7.55	4.49	5.23	4.86	4.90	5.09	5.52
Garlic	11.38	9.36	8.62	10.04	5.08	5.98	7.33	7.62	4.74
Garlic	16.24	12.99	10.83	6.62	5.43	7.98	5.19	3.85	4.13
Garlic	13.77	8.63	9.68	6.20	6.09	5.89	3.93	3.55	7.82
Garlic	9.81	10.70	12.15	7.28	5.31	4.60	6.65	4.98	4.35
Garlic	10.92	7.52	9.90	7.82	5.66	7.59	5.14	4.08	6.66
Garlic	15.54	13.72	7.84	6.90	7.65	4.05	6.71	2.54	4.79
Garlic	14.53	7.94	8.22	8.02	6.76	6.62	5.37	4.96	5.81
Garlic	7.51	13.45	7.56	6.53	5.14	5.60	5.89	4.89	5.86

Garlic	10.56	8.46	10.59	5.19	4.94	6.88	5.37	6.77	6.76
Garlic	6.41	10.59	5.46	6.19	6.78	8.31	6.48	10.10	7.18
Garlic	9.89	11.11	9.02	13.12	4.37	7.34	6.05	8.23	7.67
Garlic	13.22	10.93	9.24	5.56	4.90	5.15	4.39	5.91	6.28
Garlic	13.58	9.14	6.20	4.72	8.30	3.46	5.71	5.12	6.75
Garlic	8.90	9.37	8.30	7.67	8.56	6.85	5.46	4.94	7.83
Garlic	11.74	8.78	9.11	6.75	4.41	6.09	5.11	7.62	6.45
Garlic	12.20	12.81	11.56	5.31	6.18	8.36	4.33	6.70	4.91
Garlic	11.05	8.54	9.58	6.03	7.56	8.94	6.10	2.82	5.13
Garlic	7.65	9.70	13.52	8.46	4.88	8.34	8.31	3.51	3.97
Garlic	10.04	9.47	10.04	6.71	5.96	7.27	5.80	4.13	3.57
Garlic	9.09	11.59	5.65	8.65	6.65	4.14	4.81	5.29	4.42
Oat	10.93	7.33	13.53	6.26	7.72	9.35	4.57	8.42	5.28
Oat	15.75	13.10	11.23	5.56	7.95	8.82	10.11	4.70	8.12
Oat	9.99	14.26	11.04	9.33	6.81	7.29	6.46	4.56	6.89
Oat	12.79	12.11	6.44	8.50	8.19	7.47	9.22	4.91	10.31
Oat	12.92	11.26	8.62	7.85	7.74	6.44	4.12	6.40	6.02
Oat	10.51	12.54	7.84	7.00	10.00	4.10	7.29	5.69	4.47
Oat	14.13	8.39	7.78	7.97	5.86	6.93	8.43	5.55	8.84
Oat	11.83	13.07	9.55	9.57	5.95	8.04	7.69	6.81	7.88
Oat	11.67	10.42	12.05	5.74	7.92	9.20	6.23	5.35	6.82
Oat	10.79	13.97	7.51	8.44	7.79	7.07	4.78	6.02	3.65
Oat	10.77	9.47	8.44	8.85	6.76	4.28	4.08	10.51	4.58
Oat	9.29	9.70	7.89	8.13	5.32	7.04	6.09	4.39	6.83
Oat	12.12	10.57	9.14	6.87	4.77	7.00	5.80	7.44	5.62
Oat	8.58	11.23	6.12	7.08	7.97	7.28	6.13	4.13	10.57
Oat	9.28	8.70	8.43	11.52	10.28	9.78	7.80	4.03	4.04
Oat	10.67	9.12	8.47	6.34	6.45	8.02	7.68	7.33	5.59

Oat	12.93	12.74	9.03	7.23	9.10	4.82	6.43	3.88	6.12
Oat	10.72	12.53	7.88	6.26	6.34	5.43	6.16	5.07	5.61
Oat	14.77	8.06	5.16	9.46	4.47	5.43	6.67	7.53	6.36
Oat	18.19	9.46	8.34	6.13	8.24	7.87	9.43	6.72	4.92
Oat	10.85	8.35	11.57	8.47	3.63	4.01	5.77	6.00	4.89
Oat	12.31	11.34	11.26	9.48	12.28	5.96	6.84	6.37	4.65
Oat	11.02	12.33	7.29	8.10	5.15	4.83	4.71	3.15	6.29
Oat	10.55	11.67	12.46	11.89	6.63	5.68	6.15	4.68	10.57
Oat	11.02	9.93	7.94	7.13	9.66	5.78	6.88	4.01	3.90
Oat	10.59	10.74	8.68	5.75	5.30	4.46	5.87	2.58	4.53
Oat	13.52	10.46	6.32	12.71	9.47	3.31	5.06	3.92	5.47
Oat	11.27	12.80	7.59	9.40	4.45	5.27	6.84	3.17	9.32
Oat	13.17	9.21	5.81	10.74	5.17	6.50	6.93	4.73	6.52
Oat	14.17	11.57	10.90	7.62	3.13	7.16	3.88	3.94	7.94
Garlic + C	13.17	5.80	8.73	7.89	8.19	4.19	11.81	7.69	5.32
Garlic + C	11.21	9.52	7.51	12.79	14.37	3.93	7.06	2.37	6.93
Garlic + C	12.82	13.51	14.49	10.42	6.10	8.34	10.14	4.01	9.98
Garlic + C	10.81	10.08	9.24	9.50	7.24	5.57	5.28	6.55	7.15
Garlic + C	16.34	13.41	12.61	6.13	6.42	8.25	8.79	6.10	9.11
Garlic + C	6.97	7.75	9.86	8.12	6.74	5.97	10.82	5.72	3.90
Garlic + C	10.21	12.33	9.47	9.54	5.88	6.86	8.14	5.87	5.96
Garlic + C	13.72	5.37	9.91	8.55	5.40	7.14	4.90	9.42	6.52
Garlic + C	10.14	5.34	7.79	6.25	5.04	7.67	7.49	7.58	4.63
Garlic + C	10.05	9.13	5.46	5.51	8.38	5.36	4.73	13.59	6.99
Garlic + C	12.44	6.60	9.25	7.28	5.90	8.05	6.00	5.63	6.36
Garlic + C	5.07	8.01	7.53	6.37	6.48	6.87	6.13	5.95	5.93
Garlic + C	7.58	4.77	7.06	7.99	9.35	7.88	7.68	4.90	9.80
Garlic + C	10.36	7.03	10.67	9.09	5.00	5.50	8.96	5.69	7.29

Garlic + C	12.04	7.35	5.01	6.96	6.59	5.58	4.26	2.88	10.27
Garlic + C	8.20	7.74	7.09	3.19	6.39	6.83	4.41	4.63	5.94
Garlic + C	8.71	9.85	7.19	5.51	6.19	7.10	7.27	8.58	5.41
Garlic + C	9.01	10.39	4.40	7.84	8.02	4.57	5.02	3.62	7.94
Garlic + C	13.80	8.14	5.62	4.99	6.26	9.42	6.79	7.41	5.26
Garlic + C	12.96	15.55	4.59	10.68	5.45	5.44	7.20	2.76	4.97
Garlic + C	12.80	6.19	10.68	10.36	9.66	3.37	3.59	3.90	5.31
Garlic + C	7.74	8.76	7.88	8.23	7.95	4.50	6.96	2.62	7.50
Garlic + C	10.04	8.39	8.10	6.45	4.97	6.19	5.59	6.95	5.24
Garlic + C	10.59	8.47	13.87	6.61	4.65	4.63	6.46	5.20	5.97
Garlic + C	14.15	10.09	13.97	7.59	6.12	7.67	4.90	7.22	5.54
Garlic + C	7.58	7.76	8.39	7.94	7.00	5.82	10.76	6.04	4.97
Garlic + C	9.44	11.07	8.28	8.44	9.71	5.29	5.00	6.09	5.11
Garlic +C	11.21	7.65	8.22	9.28	5.15	8.30	4.61	6.84	4.15
Garlic + C	11.88	6.64	10.50	6.52	4.14	7.75	5.94	6.45	3.44
Garlic + C	11.51	12.06	6.84	9.41	7.20	8.13	4.75	6.01	4.13
Oat + C	12.89	9.75	7.73	8.56	4.13	5.50	4.75	4.36	3.94
Oat + C	9.45	16.87	12.10	6.59	5.76	6.01	6.34	5.96	5.16
Oat + C	8.56	5.52	11.61	3.75	7.37	5.71	3.32	6.03	4.25
Oat + C	9.75	10.63	6.99	4.59	6.80	6.19	4.49	5.51	7.33
Oat + C	11.97	10.49	5.30	7.69	8.27	3.03	6.33	4.21	4.05
Oat + C	9.78	11.13	6.42	8.58	10.68	6.95	5.59	5.26	4.73
Oat + C	15.07	7.85	10.99	7.44	5.81	7.88	3.97	8.01	5.63
Oat + C	18.29	9.52	10.34	6.50	4.21	5.47	7.55	7.27	4.61
Oat + C	17.03	9.38	6.95	4.68	6.42	4.46	8.42	6.07	6.85
Oat + C	8.40	11.59	10.12	11.62	5.67	3.33	6.89	7.94	6.08
Oat + C	9.15	10.92	7.55	8.38	8.55	6.42	3.40	3.56	4.60
Oat + C	11.80	5.83	7.87	7.24	5.29	6.21	6.22	6.33	4.45

Oat + C	17.69	7.00	7.99	7.30	5.68	4.71	5.86	3.00	5.44
Oat + C	11.40	12.05	7.29	5.36	6.64	7.01	4.69	5.85	5.20
Oat + C	12.62	8.63	6.40	7.19	8.11	8.24	6.70	7.01	5.23
Oat + C	8.52	10.74	8.53	5.00	7.25	5.88	5.76	5.35	5.28
Oat + C	10.50	12.42	6.57	6.27	5.72	6.17	7.38	4.96	7.44
Oat + C	8.42	11.35	9.23	10.22	5.42	4.95	7.05	3.82	4.69
Oat + C	7.68	9.56	5.97	5.98	7.57	4.67	6.82	2.59	6.59
Oat + C	12.79	9.80	7.21	7.41	7.49	4.07	5.45	5.11	5.45
Oat + C	10.93	10.36	10.30	5.40	4.86	5.82	4.71	7.48	7.28
Oat + C	10.60	10.45	7.56	7.42	5.69	6.81	4.36	6.03	4.30
Oat + C	12.58	6.23	10.22	6.20	4.88	11.11	7.00	5.11	11.04
Oat + C	10.56	11.33	7.72	8.92	5.71	6.17	6.94	3.62	5.77
Oat + C	12.29	9.55	8.72	8.66	10.49	7.26	5.77	3.92	7.81
Oat + C	9.14	10.94	7.05	7.75	3.83	5.06	6.93	6.16	5.82
Oat + C	12.64	9.96	8.66	10.80	4.77	6.43	5.85	5.49	3.92
Oat + C	12.74	10.41	6.53	9.62	5.44	5.29	7.07	3.44	3.99
Oat + C	11.76	9.47	7.68	6.92	9.97	4.19	4.25	3.70	3.81
Oat + C	10.44	10.68	9.06	9.89	5.10	5.89	6.76	2.12	5.24
No mulch	11.87	9.35	6.69	7.55	5.49	4.98	5.24	6.01	6.41
No mulch	14.00	8.57	11.27	6.62	7.88	6.79	6.20	5.03	8.79
No mulch	17.22	11.51	8.75	11.83	11.45	7.84	6.32	5.39	3.52
No mulch	16.68	8.70	7.15	8.39	5.07	6.74	6.65	6.35	4.19
No mulch	12.04	12.23	8.29	4.03	10.31	3.67	4.56	5.00	6.44
No mulch	9.36	6.16	10.36	10.83	3.08	8.81	6.71	3.30	3.53
No mulch	15.30	11.85	6.85	6.61	5.25	9.14	6.67	4.24	7.61
No mulch	16.02	15.00	7.46	10.21	4.19	5.59	6.40	5.41	4.95
No mulch	11.16	11.09	8.15	8.98	8.33	3.44	2.85	10.12	5.70
No mulch	13.98	14.49	7.55	5.14	4.63	3.52	4.74	6.52	6.65

No mulch	14.79	10.28	11.12	5.45	5.98	5.81	4.76	5.18	5.54
No mulch	11.20	11.71	12.62	6.57	9.65	4.70	7.36	6.70	7.77
No mulch	11.41	8.37	6.65	6.73	6.54	7.24	4.56	3.62	3.47
No mulch	9.54	11.44	7.74	7.30	5.08	6.68	4.19	6.36	6.31
No mulch	11.31	13.18	11.16	9.53	8.41	4.58	4.45	5.50	5.29
No mulch	12.10	13.25	6.28	3.81	5.89	4.55	4.68	3.11	3.82
No mulch	10.28	13.72	5.88	8.40	5.65	6.90	6.84	6.21	3.60
No mulch	8.23	7.47	4.90	5.90	5.43	6.13	6.57	6.10	3.48
No mulch	16.41	5.28	6.54	8.63	5.76	6.46	5.75	3.38	3.47
No mulch	6.90	7.81	5.84	6.71	4.64	5.51	6.32	2.88	3.07
No mulch	13.28	9.80	3.88	5.19	5.24	4.76	4.85	2.22	5.12
No mulch	12.56	10.08	10.21	7.93	5.40	9.16	6.99	5.53	4.47
No mulch	14.12	9.86	14.91	5.68	7.10	4.45	5.12	3.56	4.99
No mulch	12.78	10.01	8.06	11.00	6.46	6.01	5.48	6.74	3.17
No mulch	11.68	12.70	12.28	5.47	3.59	5.89	5.13	4.93	8.39
No mulch	10.70	9.27	9.39	6.28	8.36	7.72	7.12	5.03	8.11
No mulch	12.63	12.78	10.62	7.58	5.93	6.34	3.67	3.91	3.43
No mulch	11.70	10.81	8.09	7.84	8.74	2.90	8.11	6.27	5.03
No mulch	13.62	7.83	10.84	7.38	5.15	7.75	3.84	6.08	3.34
No mulch	10.04	10.81	7.84	9.39	3.21	2.94	6.15	6.85	5.76
No mulch + C	6.98	5.25	5.84	6.18	5.39	6.73	5.05	4.45	5.47
No mulch + C	13.26	7.22	6.94	5.18	5.79	7.60	3.68	3.90	6.52
No mulch + C	8.95	10.70	6.40	4.40	4.00	7.34	7.46	4.63	4.38
No mulch + C	10.43	11.21	7.29	5.66	4.66	7.12	5.76	4.71	3.94
No mulch + C	12.60	9.13	7.77	5.46	8.51	6.06	4.08	5.58	3.09
No mulch + C	8.85	11.19	9.06	5.42	6.86	5.32	6.27	7.46	6.62
No mulch + C	10.76	6.01	4.93	6.26	6.46	4.08	3.75	5.43	5.31
No mulch + C	9.51	6.35	7.34	4.95	6.04	2.69	5.52	5.51	7.08

No mulch + C	11.20	5.11	6.33	5.45	5.11	6.66	6.36	6.78	4.43
No mulch + C	11.52	12.18	5.97	5.74	5.33	4.14	7.18	4.50	7.19
No mulch + C	13.61	5.79	5.51	13.24	5.88	4.49	7.59	9.05	4.07
No mulch + C	11.74	8.26	5.18	6.44	4.54	5.64	5.20	4.47	7.89
No mulch + C	11.88	9.67	6.61	5.24	6.46	6.21	4.55	3.52	4.17
No mulch + C	7.92	11.24	6.22	5.10	5.11	5.26	2.64	4.96	4.18
No mulch + C	10.94	6.51	6.93	7.41	5.97	4.40	4.97	4.79	2.73
No mulch + C	9.86	7.01	7.66	7.37	5.11	3.59	3.51	5.25	3.73
No mulch + C	9.99	9.76	4.91	6.72	5.74	4.24	5.11	3.56	7.42
No mulch + C	9.52	7.08	7.55	6.78	4.16	5.58	3.07	6.50	6.26
No mulch + C	6.23	7.62	5.08	6.02	4.11	4.02	6.64	4.26	7.12
No mulch + C	10.89	8.39	5.31	6.78	4.40	3.16	4.94	4.17	3.61
No mulch + C	9.93	5.52	5.70	10.64	8.65	11.48	4.00	6.74	6.23
No mulch + C	12.48	7.73	5.10	8.01	4.53	3.81	5.62	5.83	5.89
No mulch + C	10.35	10.18	10.16	4.15	5.13	5.72	5.00	4.18	4.07
No mulch + C	9.12	11.23	7.96	7.19	6.15	6.63	5.23	3.94	4.99
No mulch + C	11.75	7.75	7.43	4.53	5.37	3.04	7.18	6.08	2.91
No mulch + C	9.35	8.94	8.91	10.52	8.60	5.72	4.24	3.39	5.30
No mulch + C	10.37	7.74	4.64	7.12	3.93	4.87	4.14	4.49	3.67
No mulch + C	9.52	6.71	9.28	7.30	4.26	4.54	4.22	6.35	3.89
No mulch + C	8.48	6.28	9.18	8.58	3.04	4.29	4.31	3.20	3.64
No mulch + C	11.21	10.19	9.33	4.55	5.52	5.53	5.95	5.27	3.60

Appendix F.2 Brix degrees

	Brix (°Bx)									
	15WAT		16WAT		17WAT		18WAT		19WAT	
Tomato Maturity stage	4	5	4	5	4	5	4	5	4	5
Treatment										
Plastic	7	6.8	6.2	8.2	7	7.8	8	7.2	8	8
Plastic	6.6	7	6.6	7	6.8	7.2	6.4	6.6	7	7.6
Plastic	7.8	7.6	7.2	7	6.6	7.6	7	7.6	6	7.8
Garlic	5	5.8	7.2	6.4	6.6	8	6.2	7.2	5.4	6.4
Garlic	6.2	6.4	7	7.6	7.4	6	6	6.8	5.4	6
Garlic	6	6.6	6.2	7.4	7	6	6	5.8	4.6	4.6
Oat	6.4	6	6	6.6	8	6.4	4.4	6.8	6	5
Oat	5.6	7.4	7	6.7	6.6	8.8	7.2	6.6	7	7.6
Oat	7.2	8.4	6.4	8	7	6.6	7.2	7.6	8	7.8
Garlic + C	6	6	6	7	7	6.2	5.8	5.8	6.4	6
Garlic + C	6.2	7	7	8	7	7.8	7.2	7.2	6	8.4
Garlic + C	7	7	6.4	7	6.4	6	5.8	7	7	8
Oat + C	6.4	5.4	7.4	7	7	7.6	6	7.2	5	6.2
Oat + C	6.2	6.8	7.8	7.2	7	8.6	5.8	7	6	8
Oat + C	7	7	7	7	7.4	7	6	7	6	7

No mulch	6.8	7	7.4	8	6.8	7.6	6.2	6.8	5.4	5.4
No mulch	6.2	7	6.2	7	7	7.8	7.6	7.2	5.6	8
No mulch	6.8	7	6.2	7.2	6	6.8	7	6	4.2	7
No mulch +C	6	7	6.2	7.2	6	7	6.2	6.2	6	5.2
No mulch +C	6	6.6	6.4	7.8	8.2	5.4	6.2	6	8	7.6
No mulch +C	7	7	7	7	7.4	7	6.8	7.4	6	7