Evaluation of rootstocks for salinity tolerance

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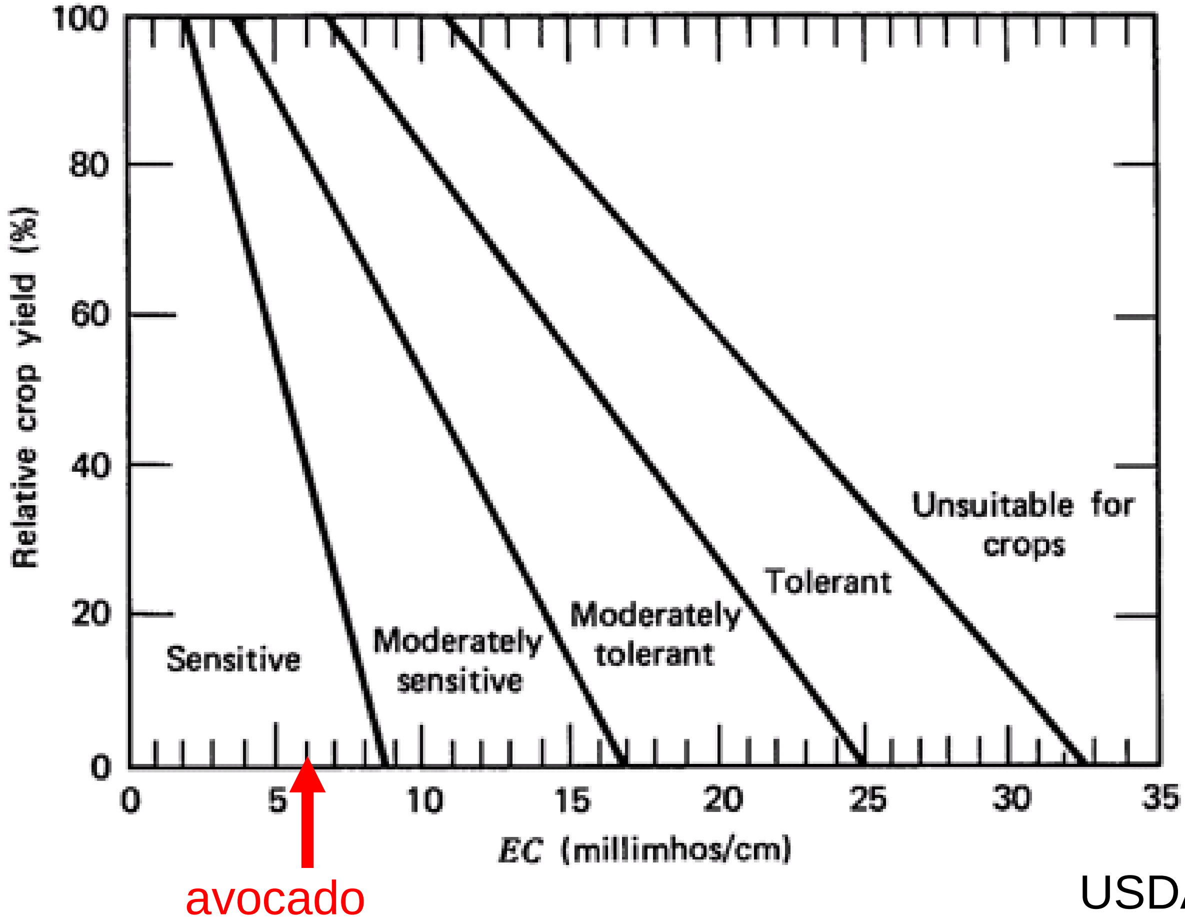
Responsibilities

- Mauk and Arpaia are supervising data collection of soil and leaf samples, documenting physiological responses of the trees to salinity and collect data on tree health.
- Suarez supervises below-ground soil mapping using multiprobe electrical resistivity (Super Sting^{TM}) technology, mapping salinity and water content distribution and calculates water use from salinity profiles and oversees all leaf and root analyses.
- Crowleywill feed data into Neural Net Analysis annually, analyze data, determine water use efficiency and nutrient interactions.

Avocado is one of the most saline sensitive crops, and is subject to yield reduction when irrigated with saline irrigation water.

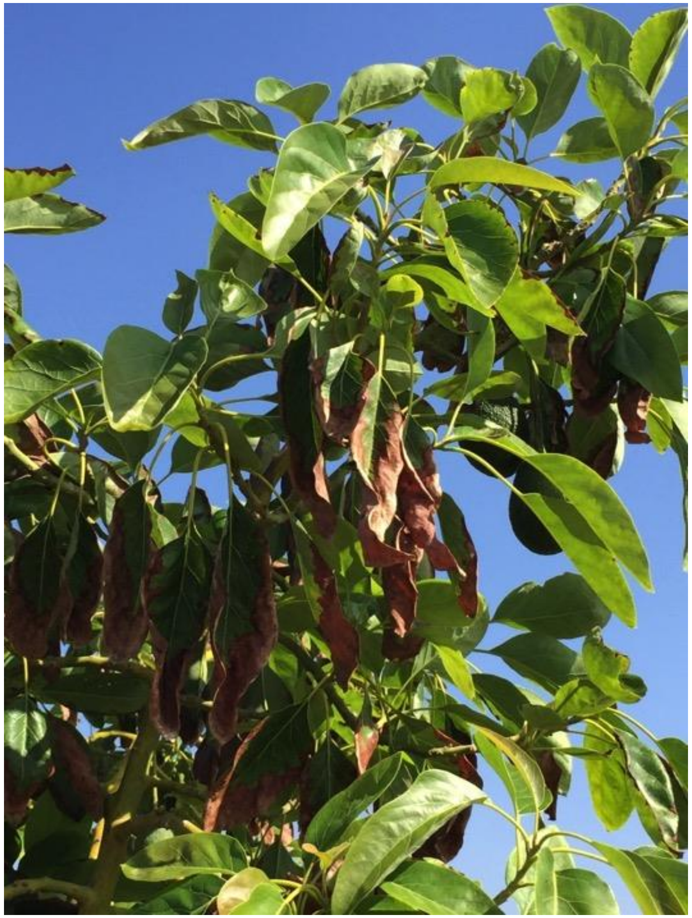


USDA Handbook 60

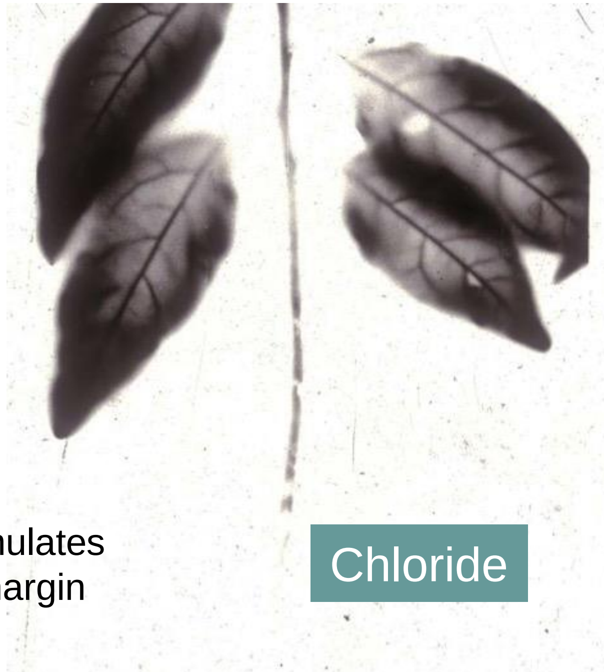
Problem

- Water quality is diminishing. Some water districts are imposing reclaimed water for agricultural users.
- Avocado is very sensitive to saline irrigation water
  - yield loss at EC levels > 0.75 dS/m and 100 ppm Cl.
- Saline irrigation water (EC > 0.75 dS/m and chloride >100 ppm) is common in California.
- High salinity and chloride toxicity cause reductions in yield, tree size, leaf chlorophyll content, photosynthesis, root growth. It causes leaf scorching, which leads to premature leaf drop.
- Tolerant rootstocks are needed to maintain yield.

Salinity Toxicity Symptoms

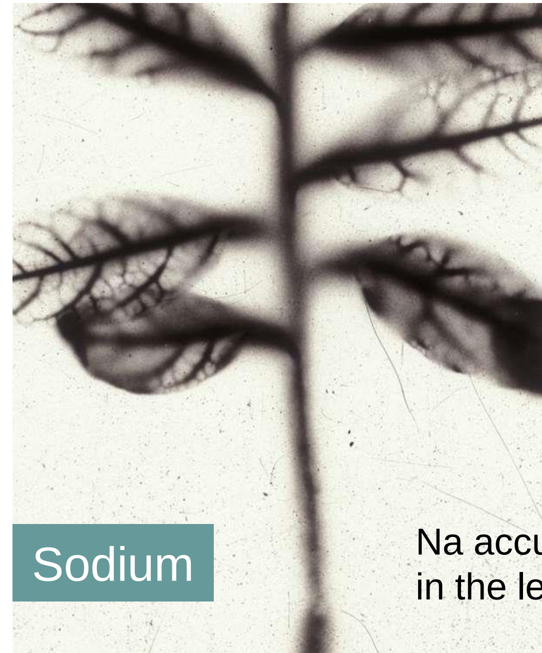


Uptake and Distribution of Radiolabeled Chloride and Sodium



Cl accumulates
on leaf margin

Chloride



Sodium

Na accumulates
in the leaf veins

(Kadman ca 1960s, slides from Platt, www.avocadosource.com)

Specific Effects of Salinity

- Specific Ion Effects, e.g. Cl, Na, B
  - Ion toxicity
  - Leaf burn
  - Photosynthesis
  - Root growth

- Reduced nutrient uptake
- Reduced water uptake
- Reduced Phytophthora resistance

The Challenge: Dealing with salinity

Short-term strategies

- Irrigation frequency
- Leaching

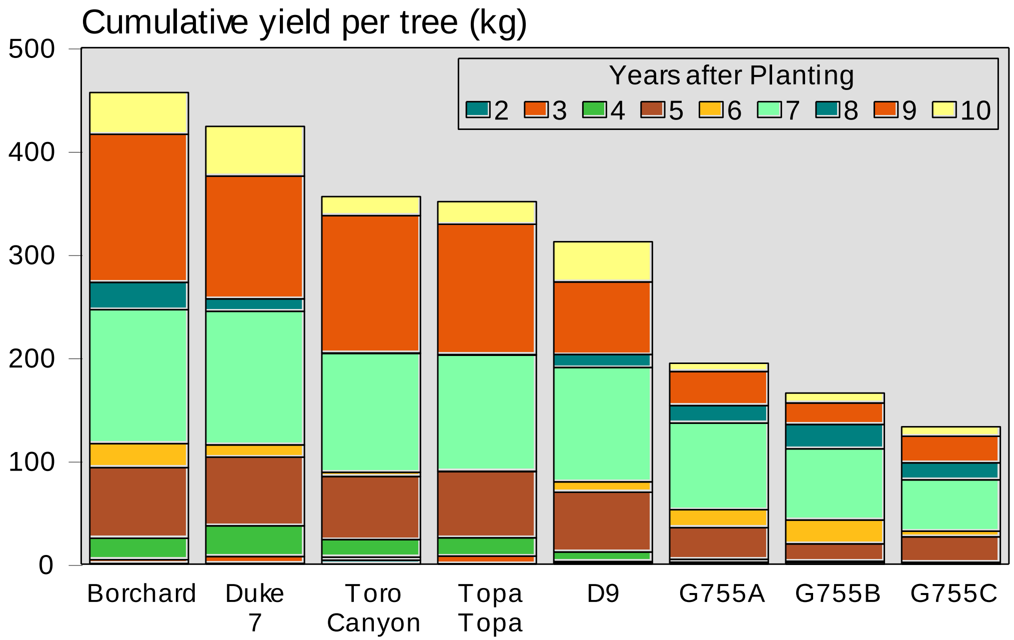
Long-term strategies

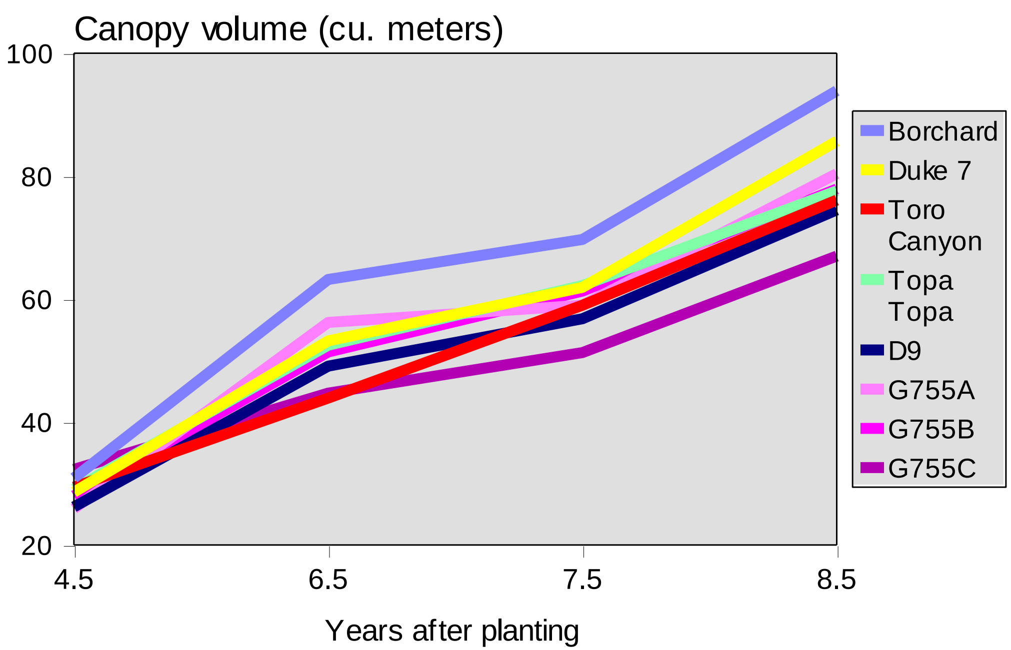
- Improved Scion material (more tolerant than Hass)
- Improved Rootstock material

The search for salinity tolerance has been led by research predominantly in Israel most notably A. Ben Ya’acov

- ✓ Identification of material such as ‘Ashdot 17’ and ‘Degania’ for use as seedling rootstocks
- ✓ Identification of VC material (vegetative clone) to be used as clonal rootstocks

As a general rule West Indian material is more tolerant to salinity than Mexican material but there is great variability within each race





Rootstock influences yield, tree size, nutrient uptake and alternate bearing

Mickelbart et al, 2007

Research Plot Background:

- In April 2011, trial was planted at UCR to evaluate root rot tolerance of rootstocks from South Africa and from UCR.
- Researcher intended to inoculate trees.
- Because of the risk of spreading *Phytophthora cinnamomi* throughout station, experiment was cancelled.
- In 2013, it was converted into a trial to test the salinity tolerance of root rot tolerant selections.

Objectives:

- Compare Phytophthora root rot tolerant rootstocks from UCR and South Africa to obtain numerical data on actual differences in salinity tolerance.
- Compare yield performance of new rootstocks at one salinity level.
- Refine current models for total water demand needed to produce high yields in relation to both rootstock selection and irrigation water quality.

Rootstock Trial, planted 4/2011

- PP14 (Uzi)
- PP24 (Steddom)
- PP4 (Zentmyer)
- PP45
- PP40
- Thomas
- Dusa
- 6 new South African
- 6 ungrafted VC *

  * Courtesy of Reuben Hofshi, VC's were planted 3/2013.

Planted in 2011 in a 11 x 21 ft planting comparing EC 0.67 with 40 ppm Cl with EC 1.5 with 175 ppm.

Field Experiment at UCR

- Randomized block design with 5 replications per rootstock per treatment.
- Installed Decagon probes which measure water availability (soil matrix potential).
- Prior to implementation of salinity treatment, leaf analysis, soil analysis, resistivity across field, photosynthetic measurements.
- Treatments:
  - Control: 0.67 dS/m with ~40 ppm chloride
  - High EC/Moderate chloride: EC of 1.5 dS/m with 175 ppm chloride

Irrigation Water Amendments and Leaching Practices

- Chloride levels were achieved by adding calcium and sodium chloride, equal amounts on an equivalent basis.
- Salinity levels were increased by adding calcium and sodium sulfate.
- We are using the ExtractChem model to prepare the salts to the desired EC.
- Salinity levels are being closely monitored and leaching will be adjusted to push accumulated salts away from root zone.
- To prevent high salts from moving into root zone, rain events will be followed by irrigation treatment.

Common salinizing salts

- Sodium (Na^{+})
- Calcium (Ca^{2+})
- Magnesium (Mg^{2+})
- Chloride (Cl^{-})
- Sulfate (SO_4^{2-})
- Bicarbonate (HCO_3^{-})

Cations

Anions

Composition of saline water to achieve EC of 1.5 dS/m with 175 ppm chloride

Compound	Concentration g/l
$CaCl_2$	1.738
$MgCl_2$	1.517
$NaCl$	0.241
KNO_3	0.063
$Na_2(SO_4)$	4.965
KCl	0.008

Treatment schedule

- Dilute salts were injected into the irrigation system beginning November 7, 2013 and the concentration was increased slowly increased to a 1.5 EC with 175 ppm chloride on Jan. 17, 2014.
- Trees are irrigated using the irrigation calculator located on www.avocadosource.com with a 20% leaching fraction.

Field trial Measurements

- Root mass per unit volume in soil cores, trunk diameter, canopy volume, chloride injury symptoms, leaf elemental analysis, flowering intensity and timing, and fruit yields.
- Physiological effects of salinity taken annually: maximum rates of photosynthesis and stomatal conductance.
- Destructive root sampling will done at the conclusion of the trial to determine if Na and Cl are excluded by roots.

What is ECe*?

- The Electrical Conductivity of a saturated soil Extract (ECe) is the most useful and reliable measure of salinity for comparing between soil types, as it accounts for soil texture.
- For example, a light sandy soil will hold much less water than a clay when both are saturated.
- However, if both have the same amount of salt, the dissolved concentration will vary between the two soils types and therefore impact on crop or pasture production differently.

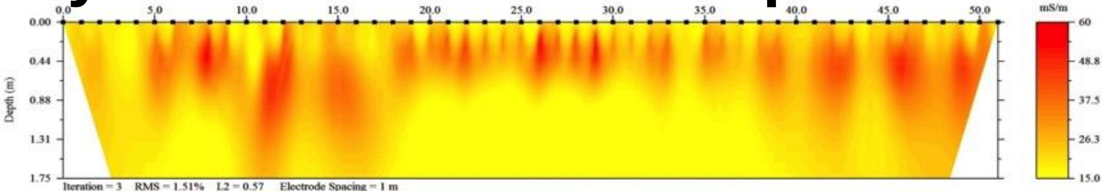
*From Wikipedia

Electrical Resistivity Imaging (Tomography)

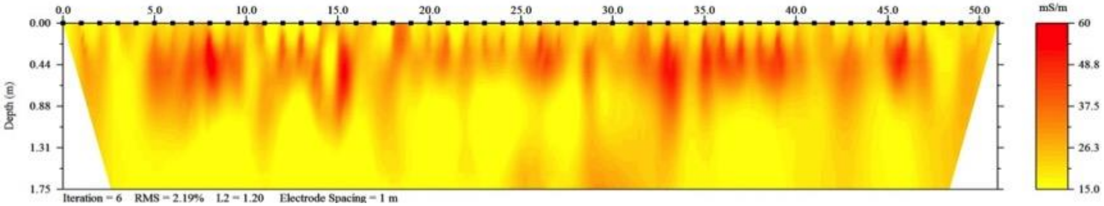
- Resistivity surveys were conducted to determine variations in electrical resistance by causing an electrical current to flow through the subsurface using electrodes connected to the ground.
- Therefore, differences in ion content (salts) can be detected and profiled down the tree row and across rows by detailed resistivity surveys.

Initial Apparent Electrical Conductivity Surveys of Avocado Field Experiment 2013

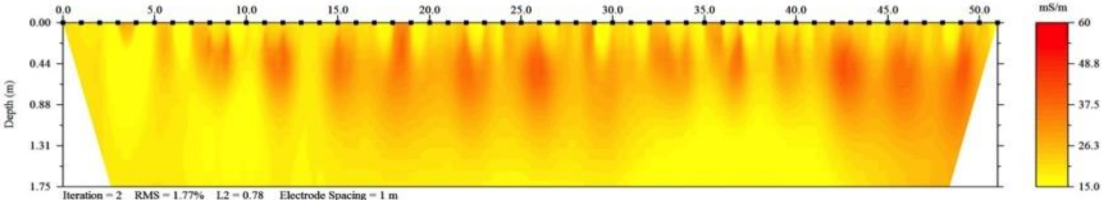
Row 21



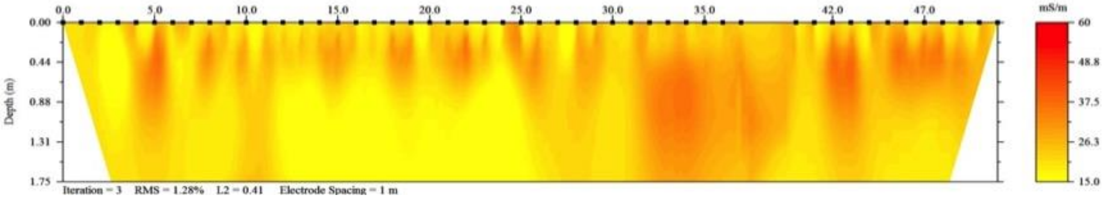
Row 25



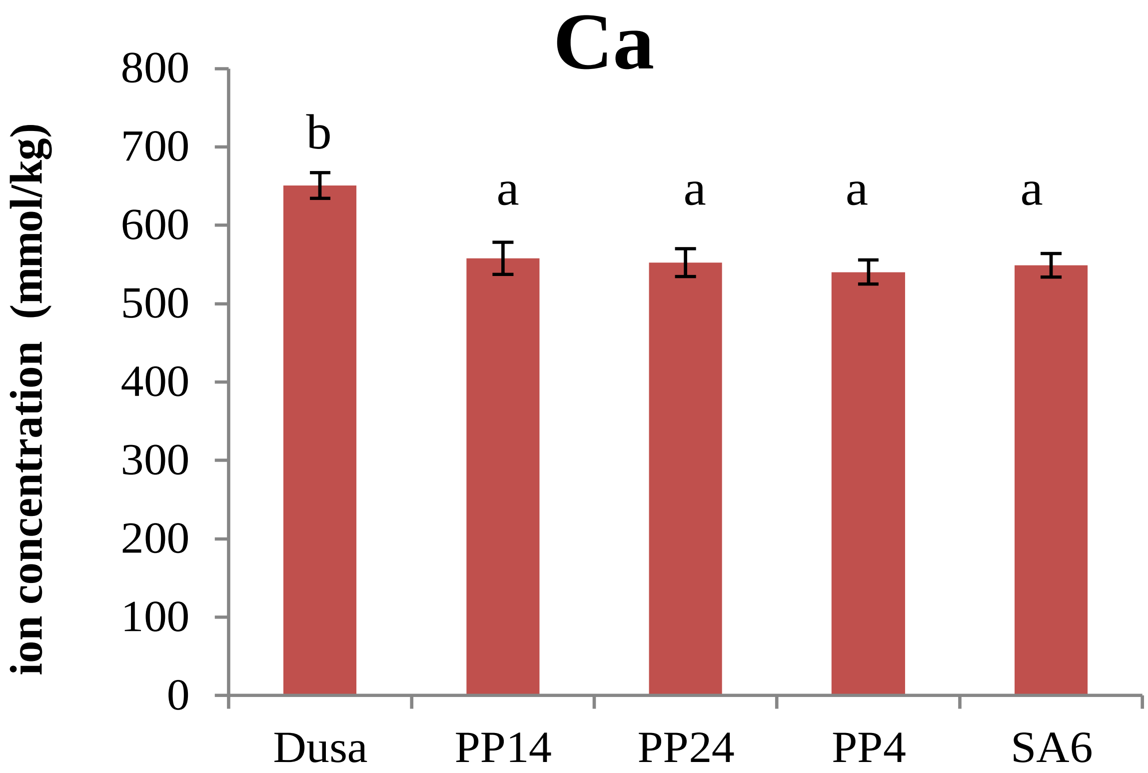
Row 29



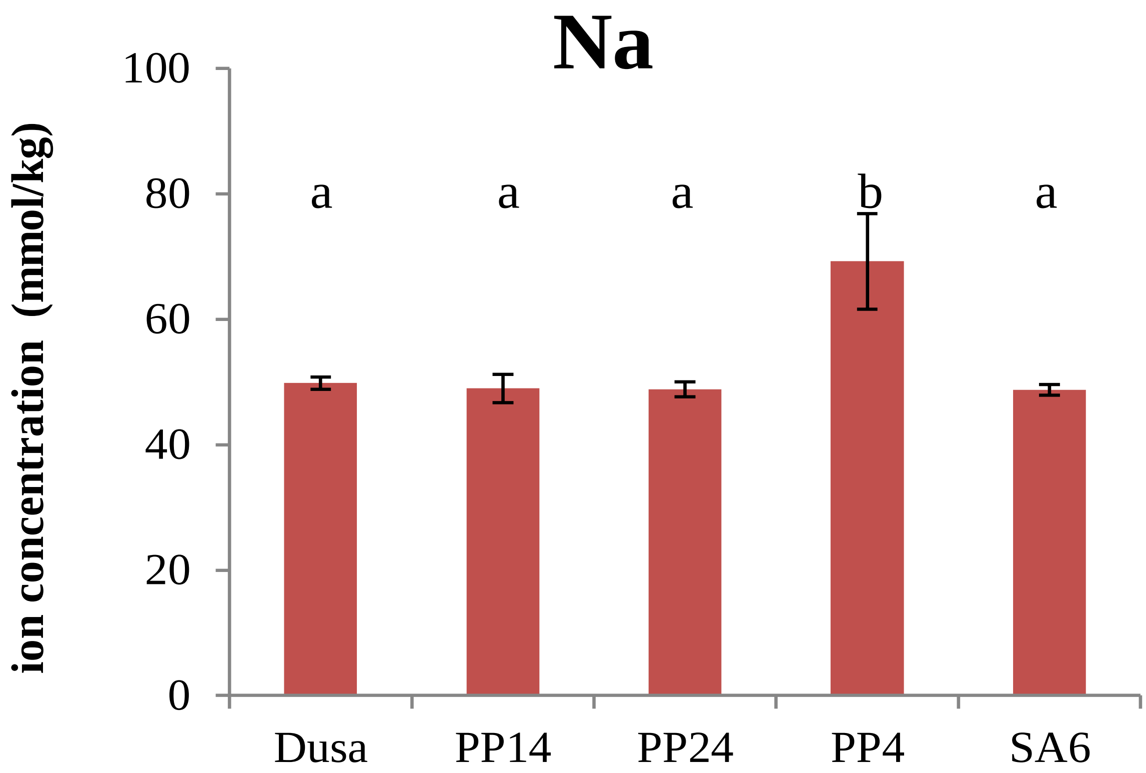
Row 33



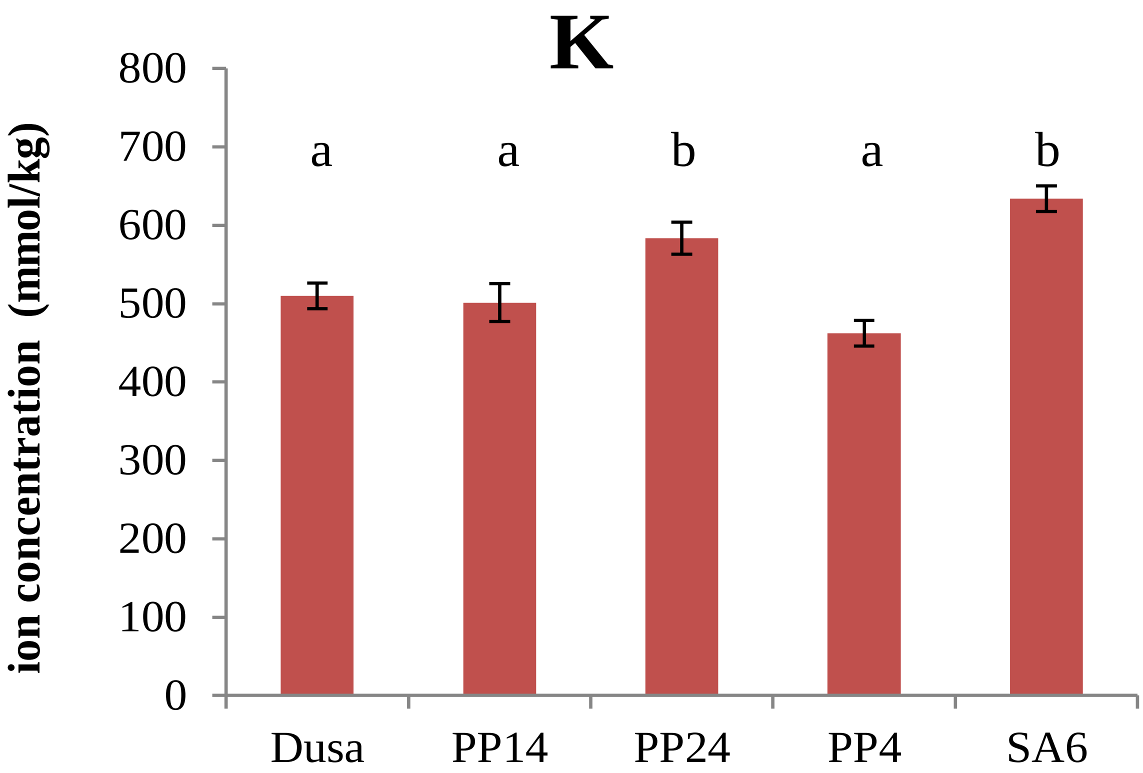
Apparent Electrical Conductivity is determined by water content, soil texture, and salinity, and in this ECa case ranged between 15 and 60 mS/m.



- Initial leaf Ca concentration as related to rootstock variety, n=13 to 22.
- Means and SE followed by different letters represent significant differences at 0.05 by Fisher LSD. Differences were highly significant only for Dusa which accumulated more Ca.



- Initial leaf Na concentration as related to rootstock variety, n=13 to 22.
- Means and SE followed by different letters represent significant differences at 0.05 by Fisher LSD. Differences were highly significant only for PP4 which accumulated more Na in the leaves.



- Initial leaf K concentration as related to rootstock variety, n=13 to 22.
- Means and SE followed by different letters represent significant differences at 0.05 by Fisher LSD. Differences were highly significant for PP24 and SA6, with higher K concentration.

Comparison of pre-treatment leaf ion composition between rows of field for fresh versus salinity treatment. No significant differences were found for any major ion. T-test at P>0.05

Results

- The March 2014 data after 3 months of application of treatments show that salts and chloride are accumulating in the top 20 cm of the soil profile in the saline irrigated rows.
- The average ECe of the top 20 cm in the fresh water treated row was 1.4 dS/m
- The average ECe of the top 20 cm in saline irrigated row was 2.5 dS/m.

Before salinization

After salinization

Salt Fresh

Dusa

Photo taken 10/2014, 10 months after full salinization.

Salt Fresh

PP 40

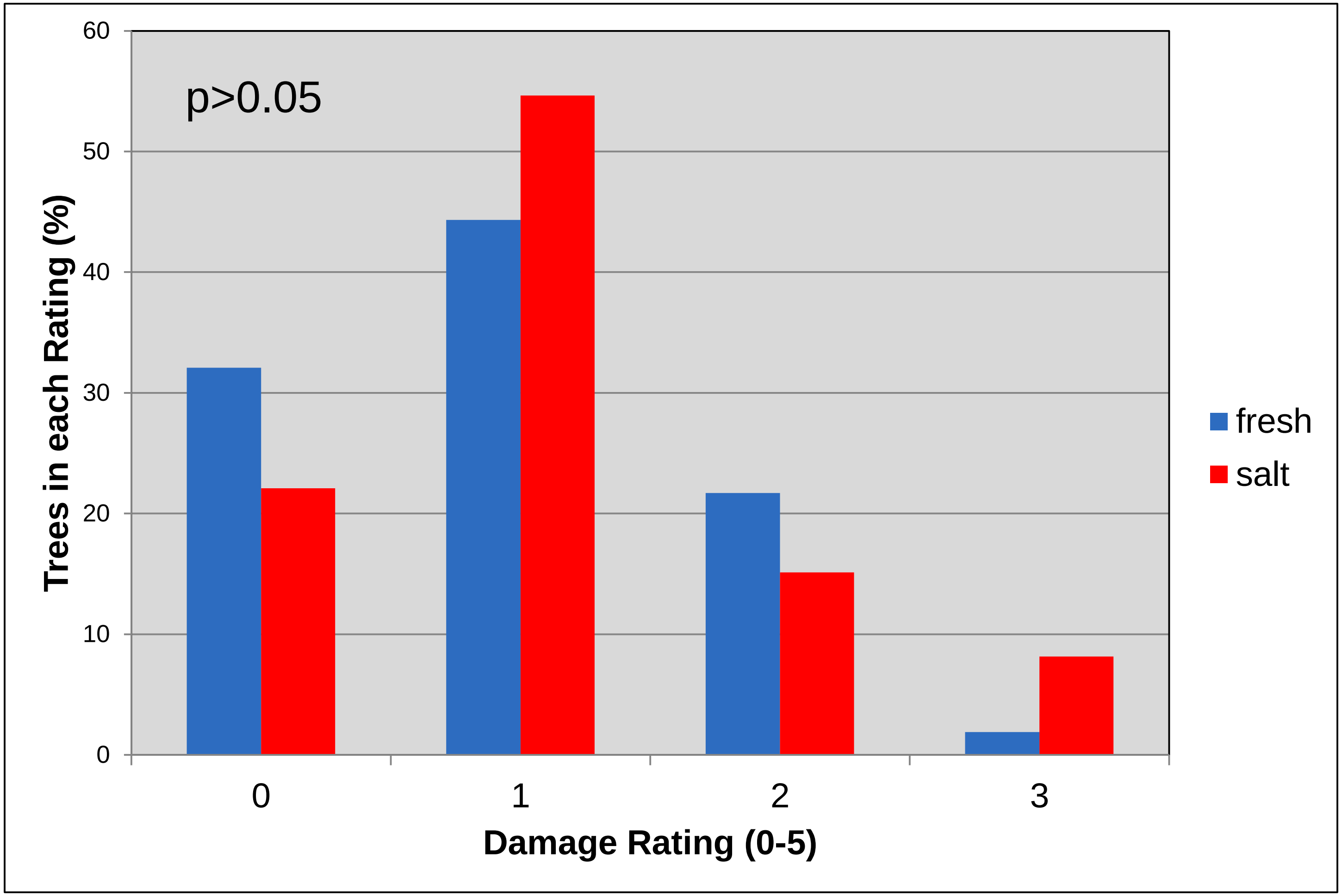
Photo taken 10/2014, 10 months after full salinization.

Salt Fresh

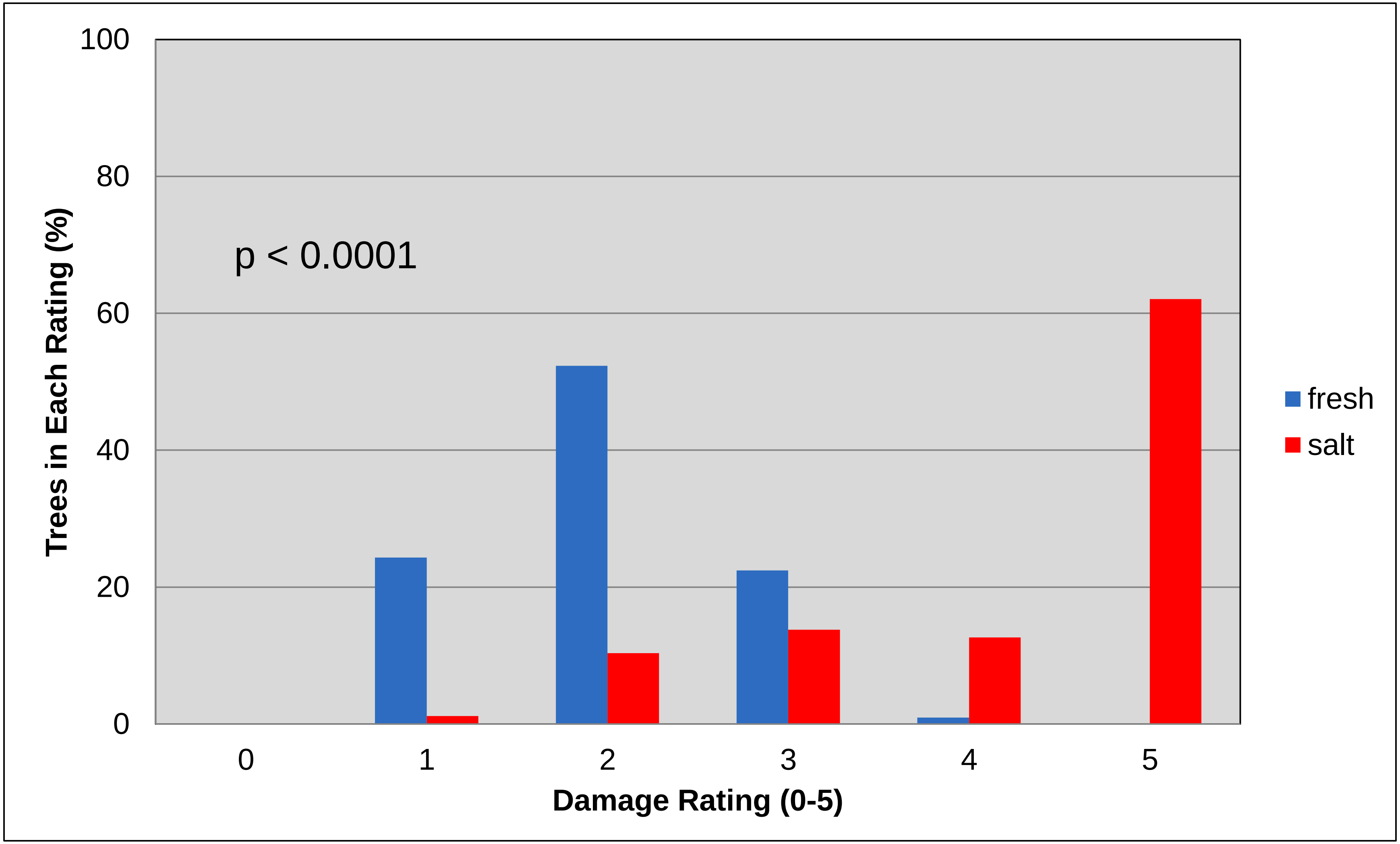
PP 4

Photo taken 10/2014, 10 months after full salinization.

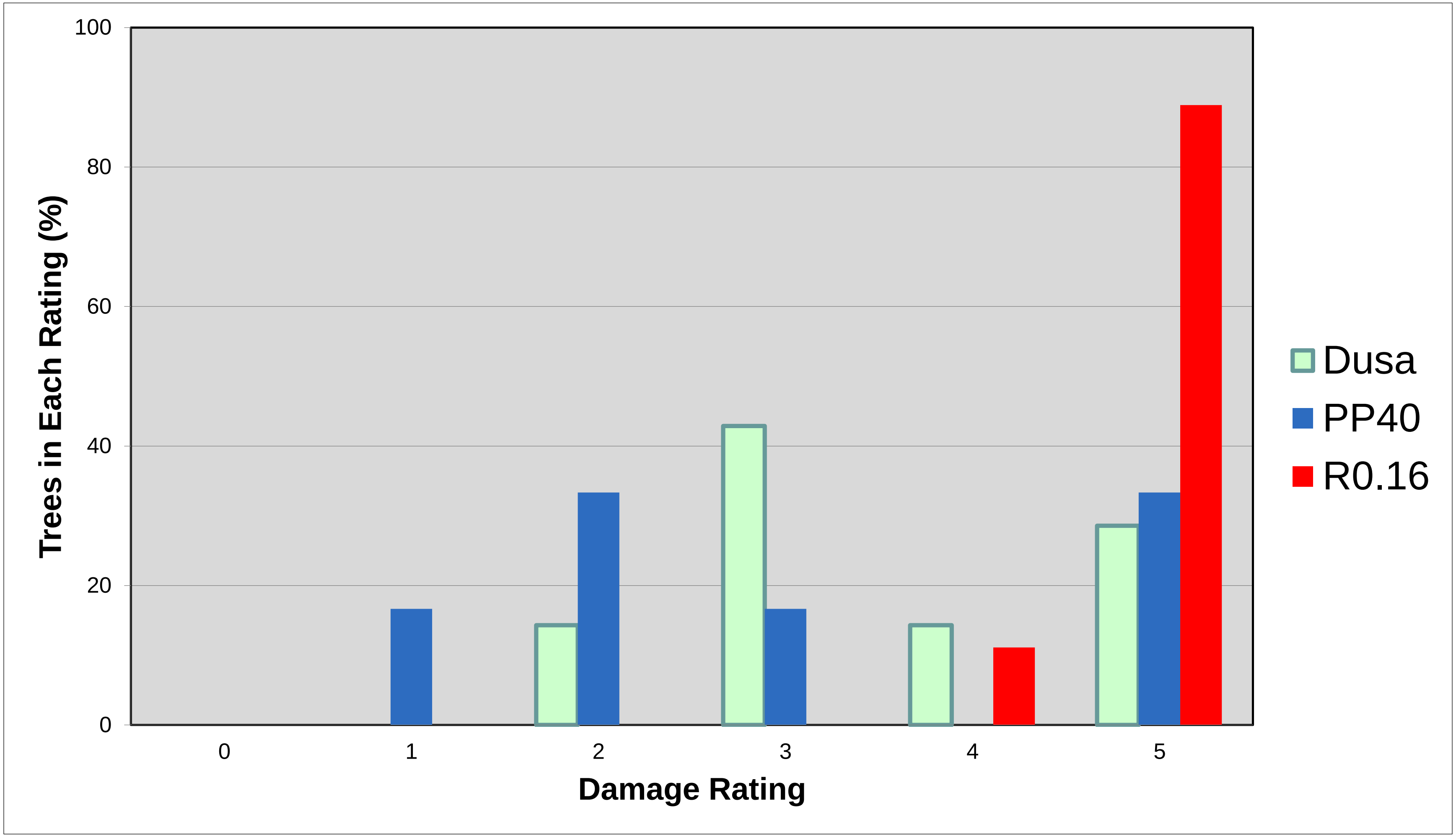
Hass Leaf Burn by Irrigation Treatment – February 2014



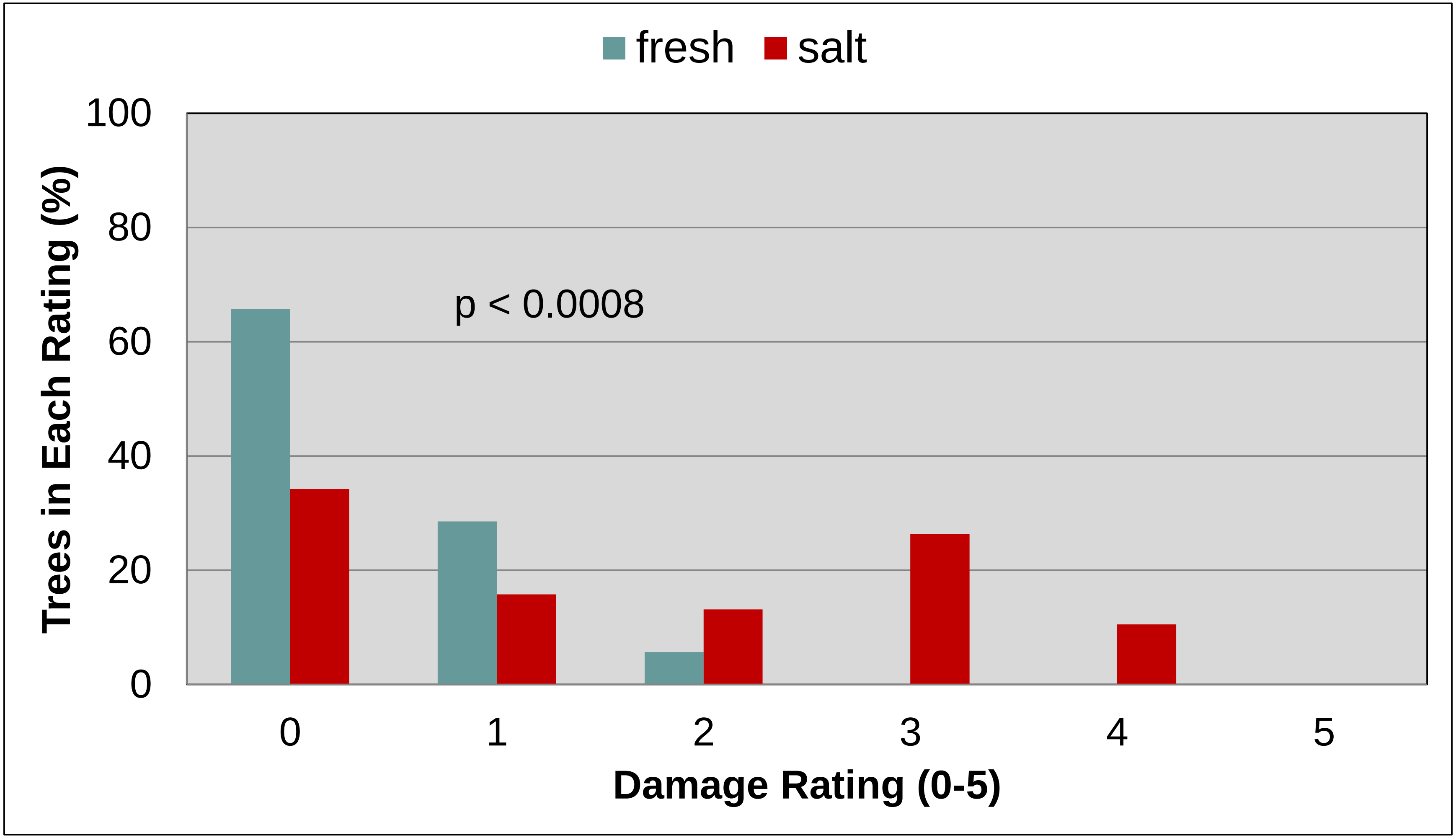
Hass Leaf Burn by Irrigation Treatment - October 2014



Damage rating of selected rootstocks, October 2014



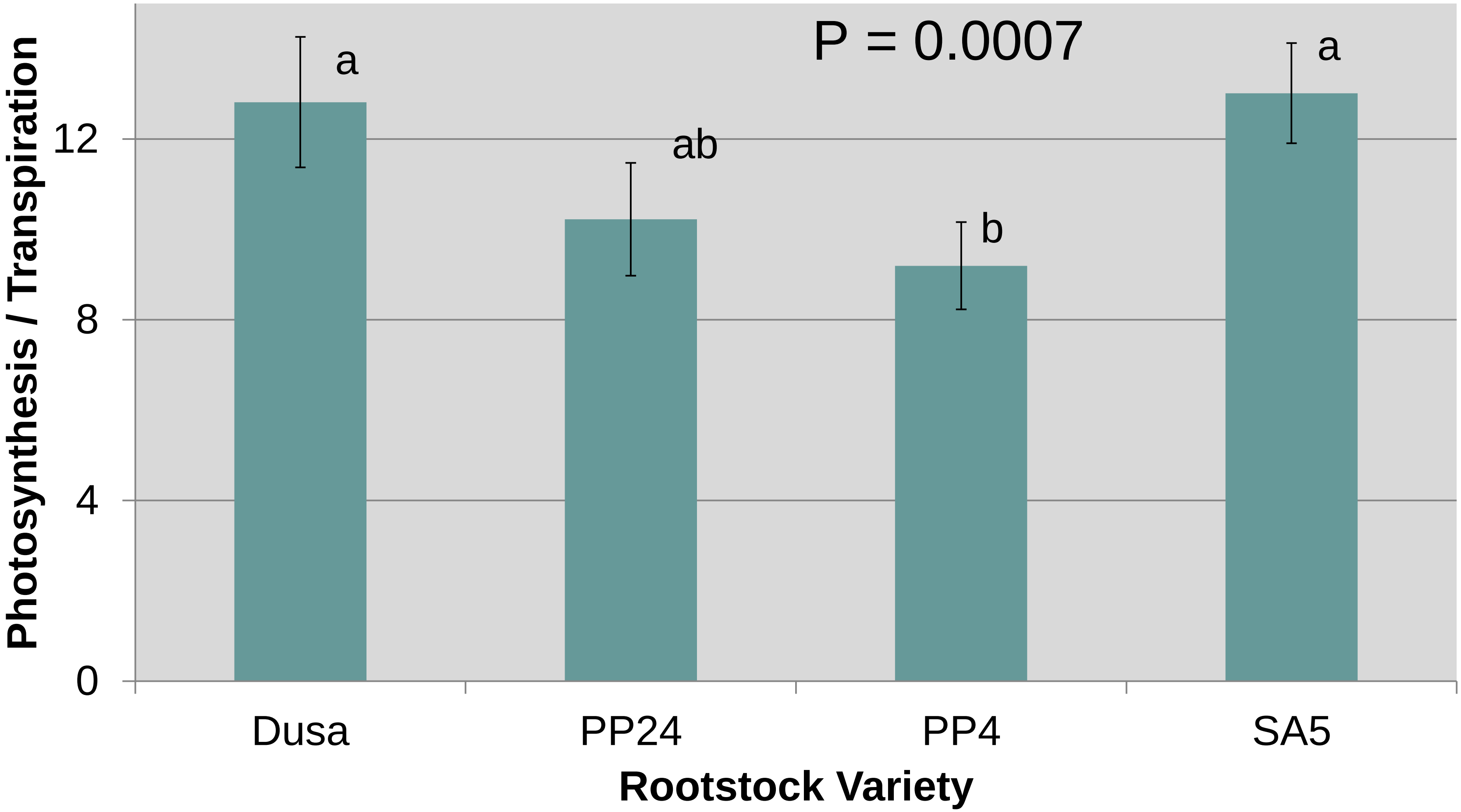
VC Leaf Burn by Irrigation Treatment



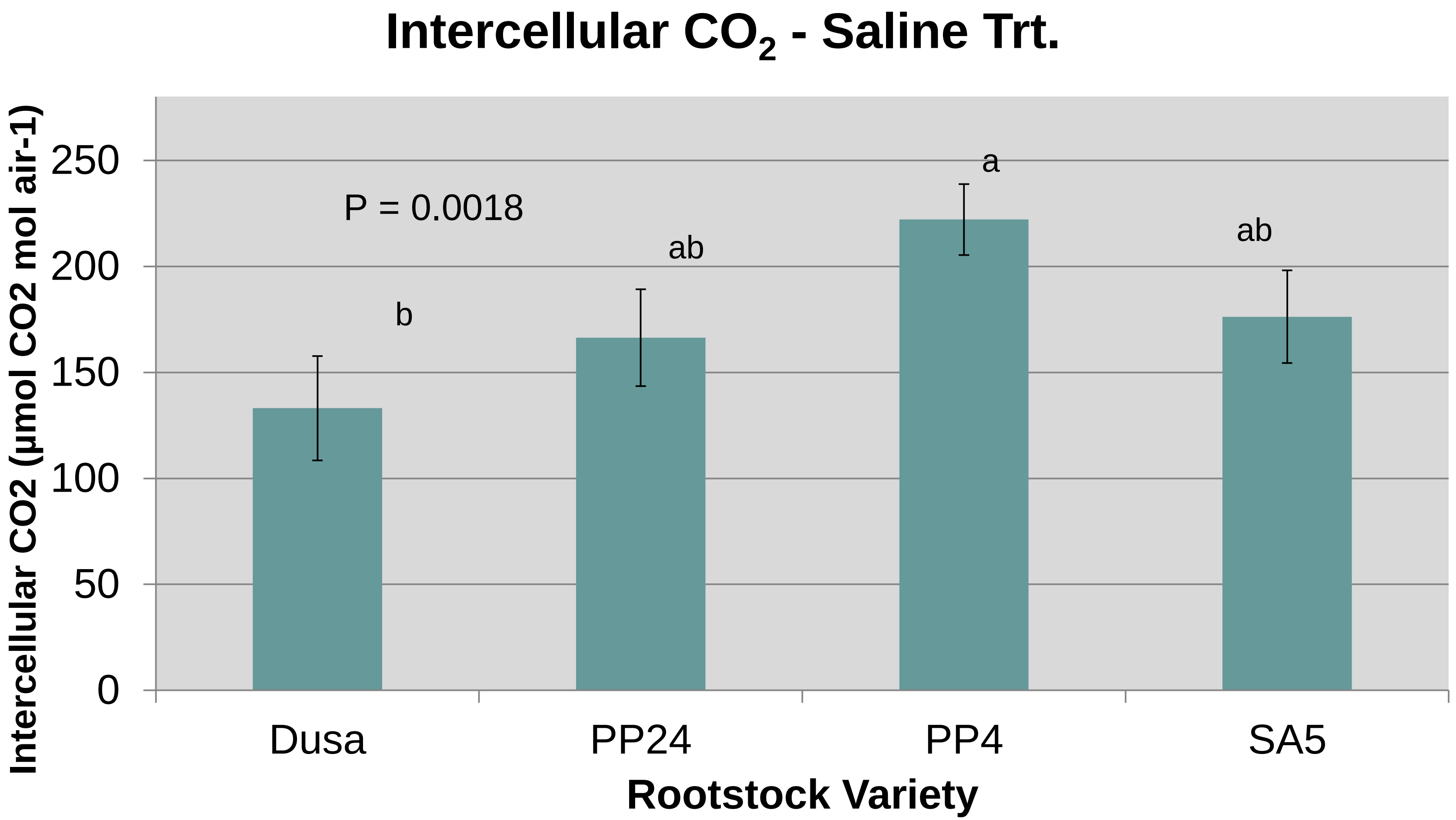
Physiological Effects of Salinity

- Physiological effects of salinity on the different varieties will be determined by measuring photosynthesis and stomatal conductance of the leaves.
- We collected data with a Licor-6400 infrared gas analyzer and a Decagon SC-1 leaf porometer.

Photosynthesis – Salinity



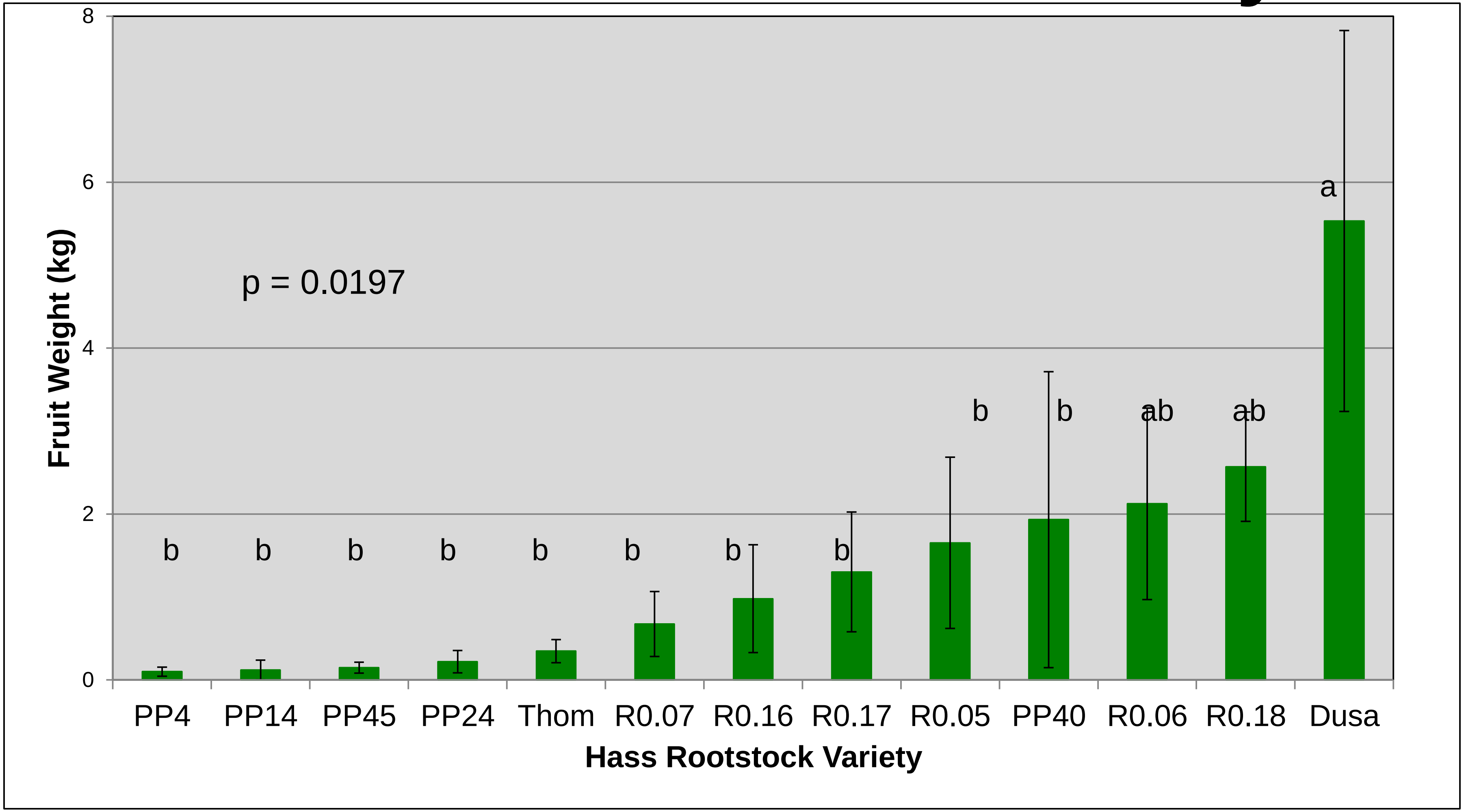
Water use efficiency



Photosynthesis

- There were significant differences between photosynthesis/ transpiration and intercellular CO_2 rates within the saline treatment but not the fresh water treatment. These are indicative of different levels of efficiency in water use by the tree

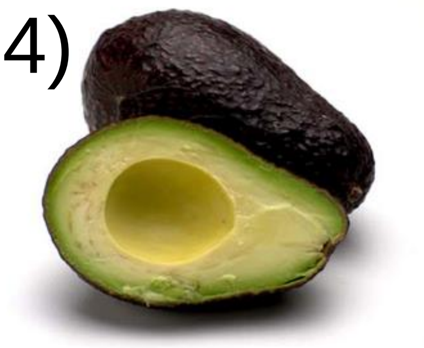
Total Harvested Fruit – Salinity



No significant difference in fruit weight between varieties within Fresh treatment. Dusa was larger than several varieties within the salinity treatment. Harvest April 2014.

Yield

- Since treatments were not implemented until the crop had set and sized, there were no significant differences in the number of fruit between treated and non-treated trees ($p>0.05$) nor total fruit weight ($p>0.05$).
- There were significant differences between the rootstocks for fruit number ($p=0.0006$) and total harvested weight ($p=0.0004$)



Conclusions so far….

- Preliminary results indicate that there are differences in rootstock tolerance to soil salinity. Some rootstocks are intolerant while others show good potential under these field conditions. Preliminary results indicate differences in water use efficiency as well as other physiological parameters.

Long-term deliverables

- Provide a list of recommended rootstocks for improved salinity tolerance.
- Provide specific recommendations for improving water use efficiency based on real time, continuous monitoring of soil water status and salinity, and the degree to which this can be improved by using different rootstocks varying in salinity

California Avocado Society Field tour – October 2014