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Response of 'Hass' avocado (*Persea americana* Mill.) grafted on Mexican and West Indian clonal rootstocks to saline conditions

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The work I am going to present today is related to my PhD dissertation. I did work in Chile with grapes and salinity, and that led me to come to Riverside and work with a salt sensitive tree; the avocado. I took different approaches from the physiological point of view in my research in order to understand how 'Hass' avocado responds to salinity stress. Today I'm going to present point "B" in (Figure 1) which is subjecting the trees to an intense concentration of salt in the irrigation water.

I. Introduction
- A. Background
- B. How to decide where to look for
- C. Today: one of the approaches

II. Dissertation Research

Growth and physiological responses of 'Hass' avocado on Mexican vs. West Indian rootstocks:
- A. Subjected to increasing Cl concentration.
- **B. Subjected to increasing salt concentration.**
- C. Expression of genes related to hormonal biosynthesis

III. Conclusions

Figure 1. Outline of Presentation.

The question that I tried to answer in my research was ascertain if there was a difference in the response of 'Hass' avocado to the osmotic effects of salinity based on rootstock. I compared different West Indian and Mexican rootstocks. I did this work because of the data reported by Oster and Arpaia, and I found it interesting that they found differences between ion concentration accumulation in 'Hass' on different rootstocks; Duke 7, Thomas, and Toro Canyon.

You can see (Figure 2) that, in the case of Thomas, just like Mike Mickelbart just reported, there is sodium accumulation in young tissues. The meristem here represents the very young expanding leaves. That accumulation in part is explained because there is a low accumulation in the roots. We see that in the other rootstocks, Toro Canyon, for example, that there is a much lower concentration in the meristem tissue.

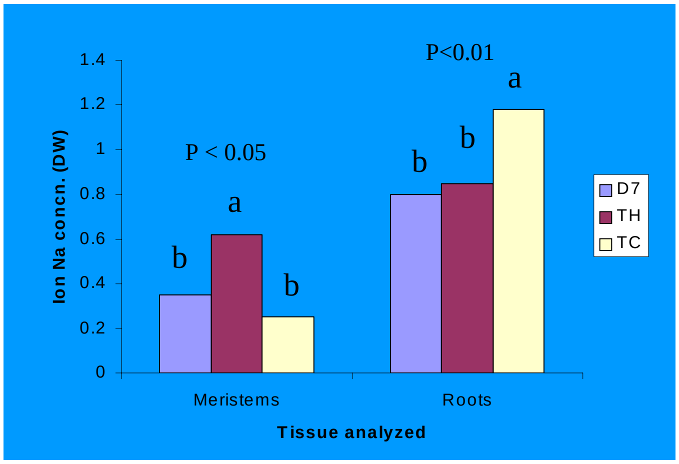


Figure 2. The effect of salinity (dS/m) on 'Hass' avocado grafted to the Mexican rootstocks Duke 7 (D7), Thomas (TH) and Toro Canyon (TC). Data from Oster and Arpaia, 1992.

In Duke 7, similar to Toro Canyon, we see a low accumulation in shoots; we can see that the ion is mainly located in the roots. So, that type of information led me to look at other types of rootstocks. And I found this work was done by Drs. Bernstein and Zilberstaine. They showed this figure earlier in this session (Figure 3). One of these rootstocks, VC 256 is one of the rootstocks that I used, and I selected this rootstock before their work was published since Dr. Menge had it available at the South Coast Field Research and Extension Center in Irvine, CA.

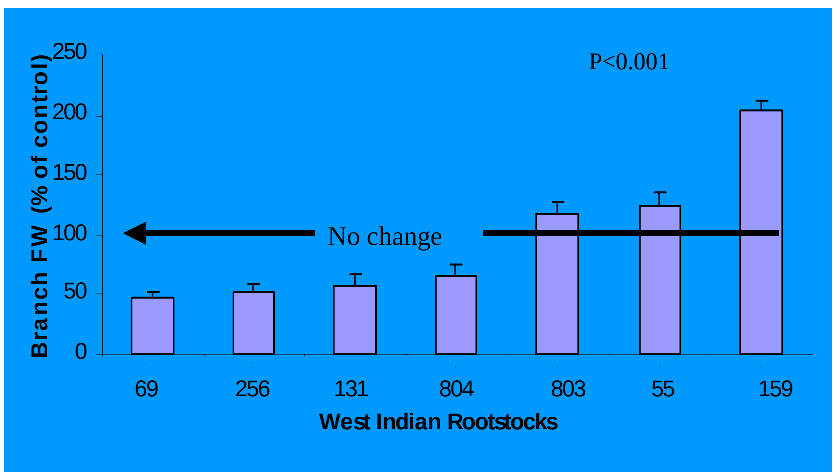


Figure 3. The effect of sodium chloride (NaCl) on vegetative growth of different West Indian rootstocks. Data from Bernstein et al, 2001.

For my research, I ended up using 'Hass' on five different rootstocks, which were Duke 7, Thomas, Toro Canyon and two West Indians, VC 207 and VC 256. I used irrigation water which had a salinity of 2, 4, 6 or 8 dS/m. In term of chloride, it was probably close to 800 mg/l of chloride for the highest concentration. I did this work at the USDA Salinity Lab in Riverside under controlled conditions; it was not a field experiment. I conducted the research as a randomized block design with 6 blocks. The trees were subjected to the 4 levels of salinity for a period of 100 days.

The evaluation included some physiological parameters such as growth, nutrition and other variables known to be related to stress physiology. For ion composition, I took the two highest salt treatments (6 and 8 dS/m) and divided the tissues into meristems (expanding leaves), the fully expanded leaves and roots. Therefore ion concentration of the data I am going to show is only related to these three types of tissue, no fruits involved.

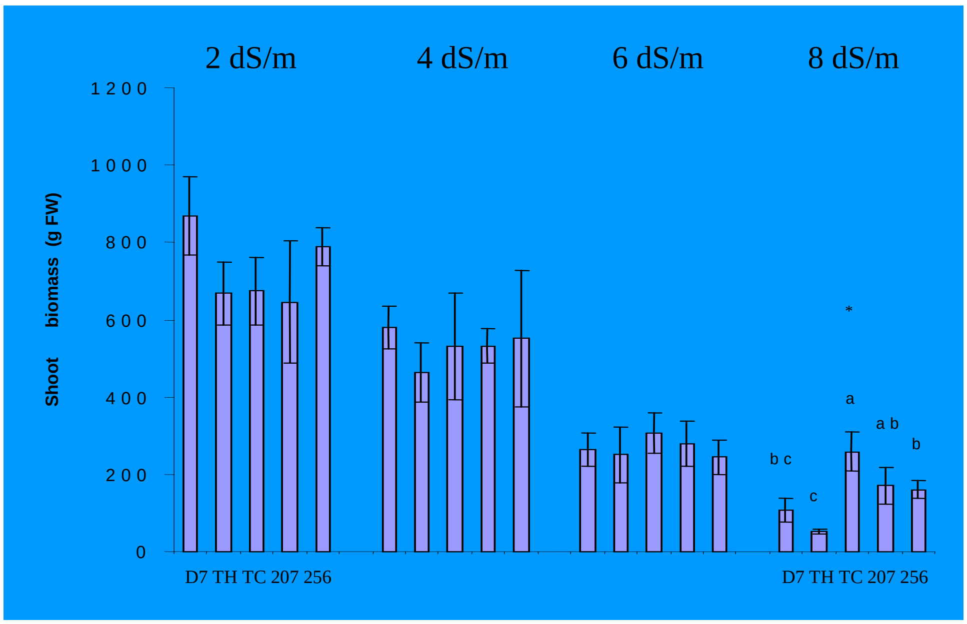


Figure 4. The effect of increasing salinity on biomass accumulation of 'Hass' on different rootstocks.

As the salinity increased from 2 to 8 dS/m, as we have seen earlier this morning, I observed a decrease in the stomatal aperture and rate of transpiration. I also observed a reduction in the delta temperature leaf-air. This is due to having less water in the leaf. Starch accumulation also decreased with increasing salinity. And I believe that was one of the reasons why I saw a reduction in leaf elongation, stem diameter, height, and biomass with increasing salinity stress. What I'd like to focus right now is on the biomass data (Figure 4). I grouped the rootstocks by race, so the first three are always the Mexican and the last two are always the West Indian race. And you can see here that, as the salinity went from 2, to 4, 6, and 8 dS/m the biomass of all of them steadily decreased. And we got some statistical differences only when we got to the highest salt treatment of 8 dS/m (Figure 4). I want to make the point here that in the 8 dS/m treatment the Toro Canyon was the one that had the highest biomass accumulation in term of shoot biomass, and the Thomas was the one that performed the worst in this case. But the West Indians, they are situated in a middle, between these two Mexican rootstocks.

When we evaluated the biomass of the ‘Hass’ trees on these different rootstocks, and when we compared the lowest salt treatment (2 dS/m) against the average of 4, 6, and 8 dS/m, we got a very interesting gain-point: that the Toro Canyon, the one that accumulated the highest biomass at the highest salt treatment, has a very positive correlation with how the roots were performing under stress conditions. In Figure 5 we have relative biomass (a value of 100% means there was basically no change between the average of the 3 highest levels as compared to 2 dS/m). When I was writing my thesis, I overlooked this data, and Jim Oster, who was my committee member, looked at this and he theorized that maybe the root has a big effect on the survival of these trees under saline conditions. To my surprise, I am currently working in a water stress lab with grass, not with fruit trees, but what I do is just look at the grass to see which one is more tolerant to water stress. As you can see, we’ve also got some differences in the stem’s growth, and there is a tendency to be different in terms of leaves and total biomass.

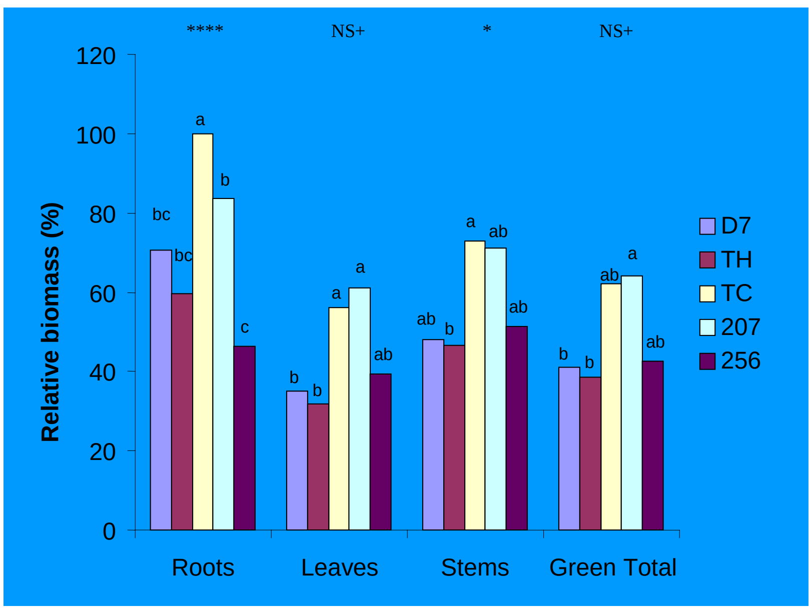


Figure 5. The affect of rootstock on relative biomass accumulation. The average biomass accumulation of the 4, 6, and 8 dS/m is compared to the 2 dS/m treatment.

Figure 6 shows that the rate of leaf expansion was depressed by salinity especially later in the experimental period.

Figure 7 illustrates how the sodium ion accumulated in the different tissues. You can see that there is a marked difference in sodium concentration in the meristem tissue and fully expanded leaf tissue between the 6 and 8 dS/m treatment.

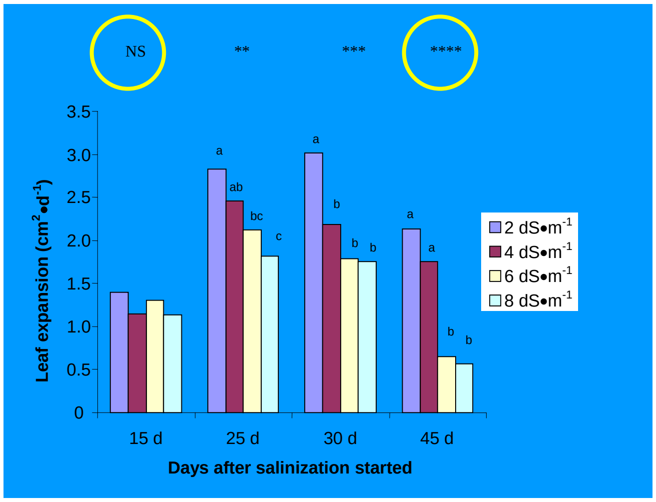


Figure 6. The relationship between salinity treatment and time on the rate of leaf expansion.

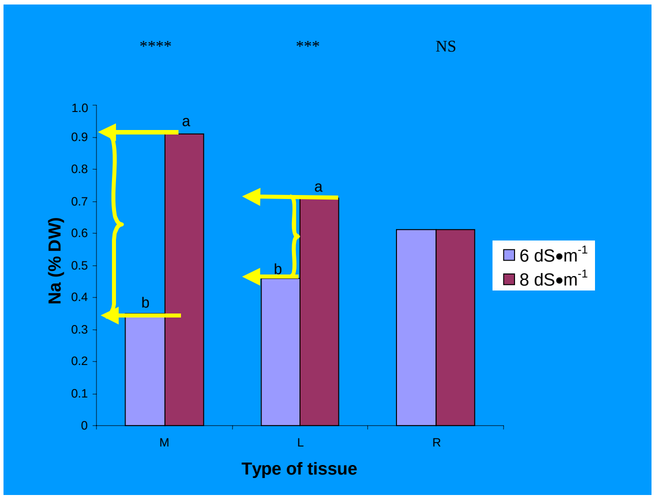


Figure 7. Sodium ion accumulation is impacted by salinity concentration.

How did the ions accumulate in the different rootstocks? We will see that the rootstocks did influence the sodium content of the different plant tissues. Here again, we have the expanding and very young leaves, which I call meristems, and we have the fully expanded, mature leaves, and the roots Figure 8).

Of course, there is an effect, more accumulation in the more sensitive combinations like Thomas and Duke 7, where you have more sodium ion accumulation in the meristems and in leaves, while the other rootstocks, Toro Canyon and the West Indians; they have lower concentration in the shoots but higher concentrations in the roots. Figure 9 uses the same data as Figure 8 but emphasizes Toro Canyon (Figure 9A), and Thomas (Figure 9B) and again, you can see the interaction.

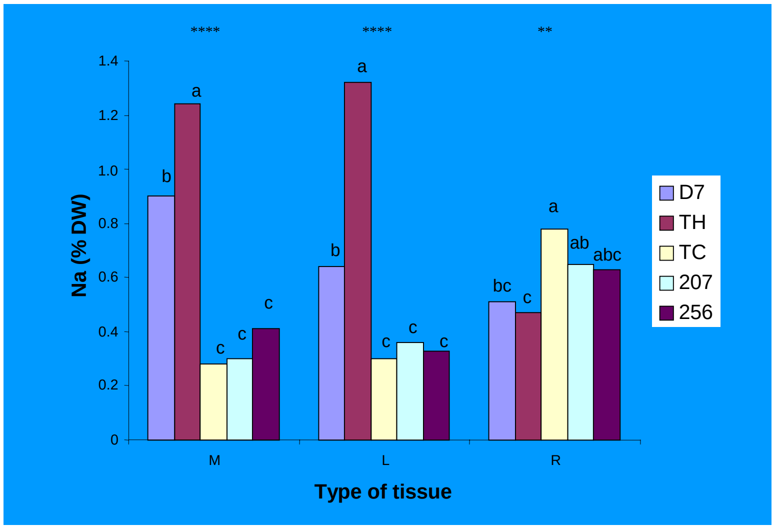
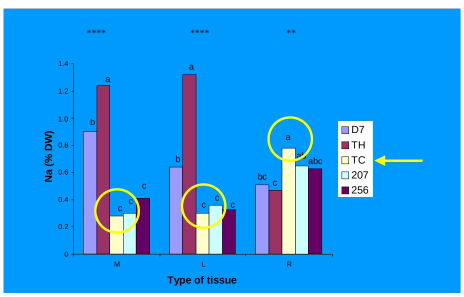
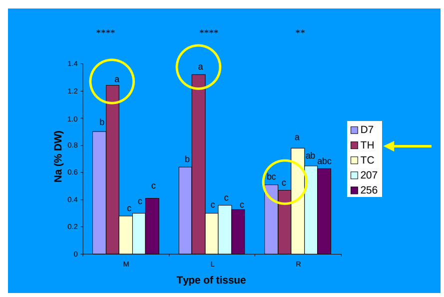


Figure 8. The influence of rootstock on sodium accumulation in meristem, leaf and root tissue. The data is the average of the 6 and 8 dS/m treatments.



A.



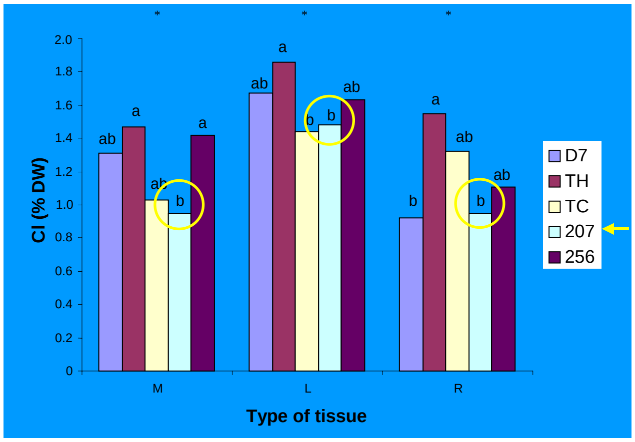
B.

Figure 9. The influence of rootstock on sodium accumulation in meristem, leaf and root tissue. The data is the average of the 6 and 8 dS/m treatments. A) Circled are the results for the Toro Canyon rootstock. B) Circled are the results for the Thomas rootstock.

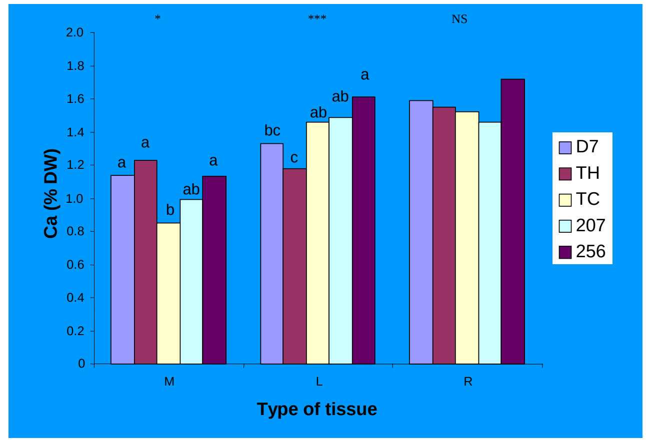
But what was interesting to me from the point of view of chloride is that one of the West Indians rootstocks, VC 207, did not show the pattern that we observed with sodium, (Figure 10A). Actually, VC 207 was associated with the lowest concentration of chloride not only in the m and in the meristem tissue, but also in the roots. For me that was very interesting because it meant that there is a way to decrease the uptake of chloride, to discriminate.

For calcium, there was a similar type of interaction with the rootstocks. VC 256 had the highest calcium, but it did not show the highest biomass (Figure 10B).

The only thing interesting in terms of N, P, and K, was that the Thomas had the highest leaf nitrogen and leaf nitrate, and, in fact, it was a very vigorous rootstock, while Toro Canyon and the West Indians had the lowest nitrogen content and total nitrogen. I didn't find any pattern associated with potassium or phosphorous in relationship to salinity or rootstock.



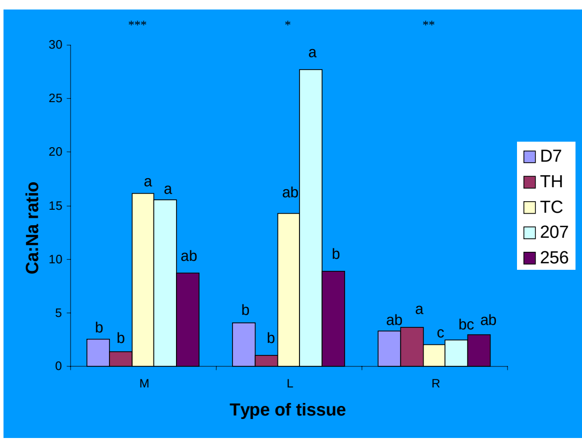
A.



B.

Figure 10. The influence of rootstock on ion accumulation in meristem, leaf and root tissue. The data is the average of the 6 and 8 dS/m treatments. A) Chloride. B) Calcium.

Just one more point that I want to touch on is the potential use of ion ratios as a potential salt tolerance trait. Viewed in this way you can see that the Toro Canyon has a high calcium to sodium ratio (Ca:Na) in both the meristem and mature leaf tissues, similar to the West Indian rootstocks (Figure 11A).



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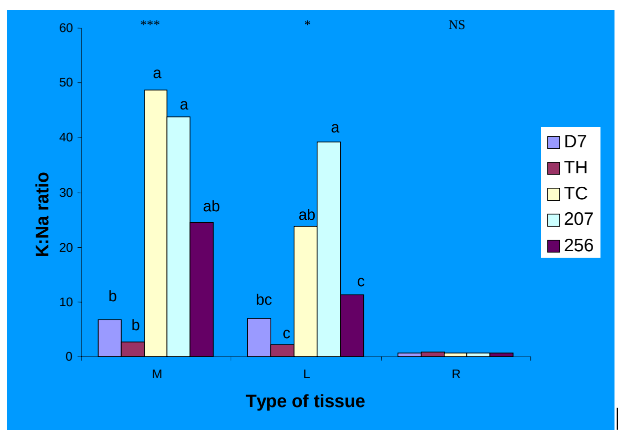

B.

Figure 11. The ion ratios for different tissues as influenced by rootstock. The data is the average of the 6 and 8 dS/m treatments. A) Calcium:sodium ratio. B) Potassium:sodium ratio.

More important than the calcium/sodium ratio is probably the potassium/sodium ratio (K:Na) which has been identified as a trait related to salt tolerance. One example is a new cultivar of wheat which can tolerate which can tolerate under controlled conditions up to 40 dS/m. The roots of this wheat have a very high potassium/sodium ratio (Wang et al, 2002). Once again, you see the Toro Canyon and the West Indians are associated with the highest ratio of potassium/sodium in the shoots (Figure 11B).

This work leads to the following conclusions:

> This work provides evidence that there is genetic variability within the Mexican and West Indian races related to salt tolerance;
>
> Salt tolerance of these rootstocks to the highest salinity levels was associated to the accumulation of sodium and chloride, although we should not disregard the potassium/sodium ratio in future work;
>
> The West Indian race rootstock, VC 207 performed quite well in these studies and shows potential to do well under high chloride conditions; and
>
> The Mexican race rootstocks, Duke 7, which has been an industry standard, seems to have an intermediate salt tolerance since it was in the middle in terms of sodium accumulation patterns.

Basically, these were my conclusions. I did additional work with the hormonal ratios that I am not going to show today. And, of course, this work, it wasn't done only by me. I had a lot of help from many people in terms of labor and in terms of funding (Figure 12). I just want to thank my committee member, Carol Lovatt, Patricia Springer, and James Oster. I also would like to thank Dr. David Crowley, Mr. Woody Smith, and Dr. John Menge for the plants that I used in this research.

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Figure 12. Acknowledgements.