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Salinity tolerance of avocado rootstocks

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That was a really good overview of salinity. I've worked in salinity for a while, and I think if you got some of the basic points, you're going to keep hearing the same things reiterated over and over. I almost wish we could keep Steve's talk on the screen because he discussed things in general terms. I and others will talk about the specifics of avocado and specifically rootstocks.

Mary Lu and I are going to do this presentation together. I'm going to start by talking about some of the things that we've learned looking at rootstocks. And we've looked at a very small number of rootstocks. What we were trying to do is to identify some of the major mechanisms for salinity damage and salinity tolerance in avocado rootstocks. Other people have done far more extensive studies looking at large number of rootstocks. I think this presentation is probably a good place to start because we'll talk about some of the mechanisms.

And I think it's important to think about how do we actually identify salt tolerant rootstocks? We all know that salinity's a problem, but how do we actually find salt tolerant rootstocks? I'm going to talk about these controlled experiments. What we mean by that is that these are typically either pot experiments, or like the experiments that we did which were in large sand-tanks. In both the conditions are very controlled, because we're trying to identify what are the mechanisms that avocado uses to deal with salinity.

From that then, of course, you can identify tolerant rootstocks. But you must bring those rootstocks out into the field, and that's where you get into field evaluations, which are more replicated experiments, under field conditions. It is very important to conduct field evaluations, and most of the people up here have far more experience than I do with these types of evaluations. This means going out into growers' properties and saying, yes, this rootstock *is* performing well under salient conditions. So that's sort of how we're going about identifying valuable rootstocks.

The study that I'll talk about is one that was published a few years ago. We were looking just at three rootstocks, Thomas, Toro Canyon, and Duke 7. I'll be showing salinity levels as EC, electrical conductivity. The measurements we did were to look at growth, some of the physiology underlying some of the growth differences that we saw, and also ion relations. We're actually working on another paper looking more specifically at ion relations from this study. And, rather than give you lots of tables and graphs, I figured I would just give you the bullet points and hopefully lead us into some good discussion.

What did we find? First of all, photosynthesis is decreased at very low salinity levels. So, okay, that's not surprising, but it really supports what Steve was saying earlier, that we don't know exactly what the tolerance level of avocado is, but we know it's very low. As soon as we put salt on avocados, photosynthesis starts to decrease, and this is actually very important in California.

The other thing, growth, it was reduced at very low salinity levels, so, as soon the trees are exposed to saline soils, you get growth reduction. But in contrast to photosynthesis, with growth we start to see rootstock differences. We can start to identify some rootstocks that grow better under saline conditions. We have data to support the idea that the oldest leaves are affected most by salinity.

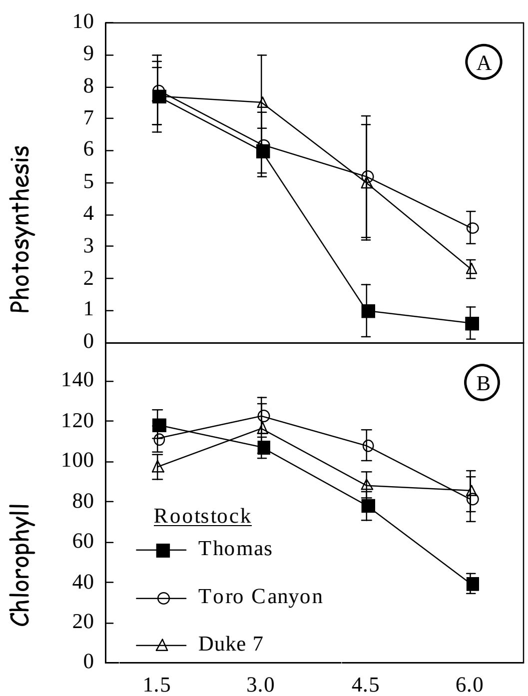

Figure 1: *The impact of varying levels of salinity on net photosynthesis (A) and leaf chlorophyll content (B) for 'Hass' avocado grown on 3 clonal rootstocks.*

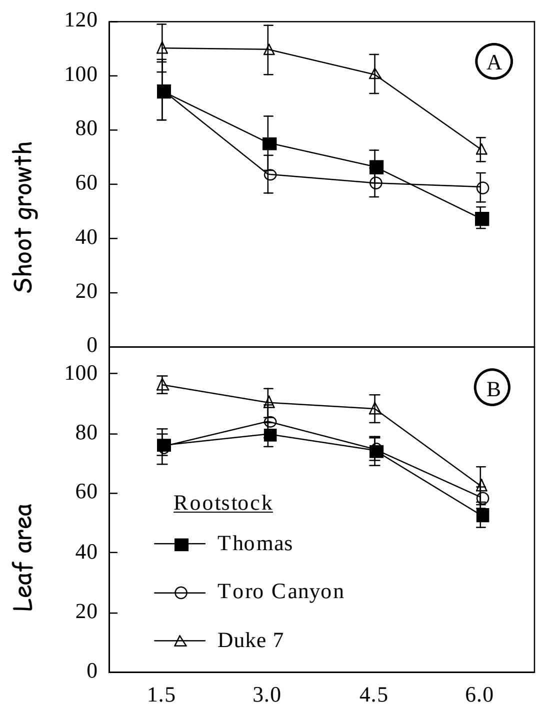

Figure 2: *The impact of varying levels of salinity on shoot growth (A) and leaf area (B) for 'Hass' avocado grown on 3 clonal rootstocks.*

Here's the photosynthesis data. (Figure 1) The numbers aren't important. I didn't even put the units up here. These are four different salinity levels, going from 1.5 dS/m , which is probably a level that a lot of you are dealing with right now, up to about six. And, again, you can see immediately that we get a decrease in photosynthesis with increased salinity. The plants are not handling the salinity very well at all.

Shoot growth under the four salinity levels is presented in (Figure 2) Again we see a general decrease in growth, but Duke7, in our study, actually handled it quite well. It was still growing, at 4.5 dS/m very similarly to the plants growing down at 1.5. Thomas and Toro Canyon didn't do so well. You see growth reductions immediately when you go from 1.5 to 3 dS/m. There are two points to emphasize here: one, they are very sensitive, and that we can identify rootstock differences.

The idea that the oldest leaves are affected most by salinity, not surprising, as Steve said. Slightly complicated table (Table 1), but what we have are the three rootstocks, Thomas, Toro Canyon, and Duke 7. There are four salinity levels. As most of you know, avocado trees grow in flushes. You get a flush growth, it stops for a while, you get another flush of growth, etc. Thus, Flush 1 would be the oldest flush on the tree when we were doing the study. Flush 3 is the youngest flush on that tree.

Table 1: *Percent necrosis of 'Hass' avocado leaves from three flushes on three rootstocks exposed to four salinity levels (n=16) for 10 weeks.*

		Salinity ($dS \cdot m^{-1}$)			
Rootstock	Flush	1.5	3.0	4.5	6.0
Thomas	Flush 1	0.18	2.50	18.37	60.55
	Flush 2	0	0	2.13	29.64
	Flush 3	0	0	0	3.24
Toro Canyon	Flush 1	0.14	0.08	5.64	11.17
	Flush 2	0	0	0.13	1.78
	Flush 3	0	0.07	0	0
Duke 7	Flush 1	0.19	0.33	9.66	29.08
	Flush 2	0	0	5.26	12.70
	Flush 3	0	0	0	0

These numbers are percent necrosis. 29/30, that's 30% of the leaf is actually necrotic from the salinity. We can see that necrosis is increasing with salinity. If we look at Flush 3, the youngest leaves, there's almost no necrosis whatsoever. And these older leaves, show quite a bit of necrosis. In fact, if we look just at the highest salinity level and at the three rootstocks in Flush 1, these are the oldest leaves, we can see a huge difference among these rootstocks. In Duke 7 we've got about 30% necrosis, Toro Canyon about 11%, but in Thomas there was 60% necrosis. 60% of the Thomas leaf area is necrotic, because of salt!

So, again, we're seeing some rootstock differences here. The oldest leaves are most affected. Why is this important? Tomorrow, in the light interception panel, I'll be talking about different leaves and how they respond to light. In California, I think, that it's really important to try to keep these older leaves as healthy as you can for as long as you can

These older leaves tend to fall off in California. Now I'm working in New Zealand, and it is still amazing to me to go out and look at trees in New Zealand and you see three and four flushes with just beautiful leaves on a branch. And here you don't see that. Those older leaves tend to fall off and there is a number of reasons for that. But salinity may be one of those reasons why we're seeing these older leaves drop. If you have lower leaf area, you're going to have lower productivity because you've got lower overall photosynthesis. So salinity may be a major contributor to reduced leaf area and photosynthesis.

We've talked about the growth and some of the characteristics. I showed you that Thomas wasn't doing very well in our study. Well, what this correlated to is sequestration, or the ability of the rootstock to keep sodium, and chloride to some extent, in the roots and in the woody parts of the plant, as opposed to letting these salts get into the leaves.

We published a paper in "Subtropical Fruit News," six years ago, and we presented a sort of a cartoon of the three rootstocks, and we showed, very clearly, with this cartoon, that if you could see the tree and you could actually see where the sodium was. Most of the sodium in Thomas was winding up in the leaves, and that's what is giving you the necrosis and the decrease in growth. Whereas, with a rootstock like Duke 7, most of the sodium was still in the roots and in the woody tissue, so it wasn't getting into the green tissue that's so important for photosynthesis and growth.

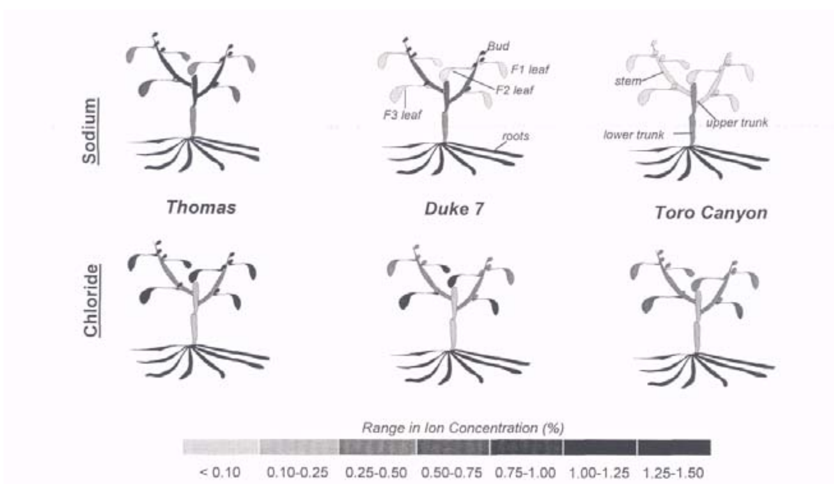

Figure 3: *Differences in salt partitioning in 'Hass' due to clonal rootstock following exposure to 6 dS/m salt. Shading of the different parts of the figures refers to ion concentrations on the bar below. Several different portions of the trees were sampled: roots, the trunk below the bud union, the trunk above the bud union, stems, leaves developed prior to salt stress (F3), leaves developing at initiation of salt stress (F2), juvenile leaves (F1) and apical and axillary buds.*

In my opinion, and we can debate it, it's the toxic ion effects that are important. I didn't show you leaf area data but leaf area didn't really change very much. When we looked at some of the water status parameters, water status didn't change very much, which would be an indication of osmotic effects of salinity. Those things didn't change very much in response to salinity. What changed is the amount of sodium and chloride in the leaves. So tolerance clearly is correlated with the ability of the plant to sequester these toxic ions in the roots and woody tissues.

The other thing, which will be presented in a paper that we're preparing now, nutrient imbalances, may occur. This is something that growers need to be aware of, that it's important, if you are dealing with saline soils, is to keep an eye on your other nutrients. We just looked at potassium, magnesium, and calcium. Potassium didn't change very much in response to salinity, but magnesium did, magnesium was decreased, not by a huge amount, but it was significantly decreased with increased salinity. Calcium was also, but to a lesser extent, decreased. So this is another point I think that you need to be aware of when dealing with salinity. Not only are you dealing with toxic ions, but they can also influence the uptake of other ions.

Mary Lu, will talk about some of the field observations that have been made in a project headed by Dr. David Crowley in the Department of Environmental Sciences at UC Riverside.

Mary Lu Arpaia

When we carried out this study, it was done in the laboratory under what Mike called controlled experimental conditions. The question is, what does that mean in the real world? And so, about the time that Mike was finishing this project, David Crowley from the Department of Environmental Sciences at U.C. Riverside became interested in working on avocados, and I began working with him. What I'm going to show you now is really results from David Crowley's project. He sends his regrets. He had a previous commitment that precludes his participation in this meeting.

He started doing laboratory studies screening some of the material from John Menge's rootstock development program. But, more importantly, we tested some of the material that we were able to import from Israel from Dr. Ben Ya'acov's program. I think, as we go through the rest of today, you'll see the importance of the contribution that people like Dr. Ben Ya'acov have made in terms of germplasm conservation.

The objective of Dr. Crowley's program is to compare salinity tolerance of current and new material from John Menge's *Phytophthora cinnamomi* resistant rootstock breeding program. Certainly *Phytophthora* tolerance is a very important, and the foundation of our rootstock selection program. But, as Ben Faber indicated in the last session, we can be sort of myopic about this and forget that there are other factors that influence productivity and tree performance. And one of these, certainly, is salinity.

Another objective of Dr. Crowley's program in conjunction with Dr. Menge's, identifying new rootstocks, is to develop and test irrigation management strategies. We're not very far along the road on this program.

Dr. Crowley has a number of projects initiated. The oldest one is at Stehly Ranch in Pauma Valley, where we have set out a trial a couple of years ago. We've had problems with that trial. And so, within that trial now, we've planted a new trial. These have just been planted in the last few months. And I would have to acknowledge definitely here, the assistance of Gary Bender, who's been the point person in this project.

Also this year, we've established a rootstock trial up in Santa Barbara County, at Pete Miller's grove. This includes seven rootstocks, and this is the first trial we're putting out where we have the Lamb Hass and Hass actually grafted on the same rootstocks. This site has heavy soil, root rot, and salinity. So it has a little bit of everything, plus a little wind thrown in.

Dave has also established a project with the Cavalettos in San Louis Obispo County. Harlan Beck is a site in San Diego County, where we're planting seedlings from the Menge program in a high saline condition. We are also collaborating with John Menge in some of his root rot plots which also have salinity problems. This is actually a work in progress. This is all work that's been initiated in the last three to four years.

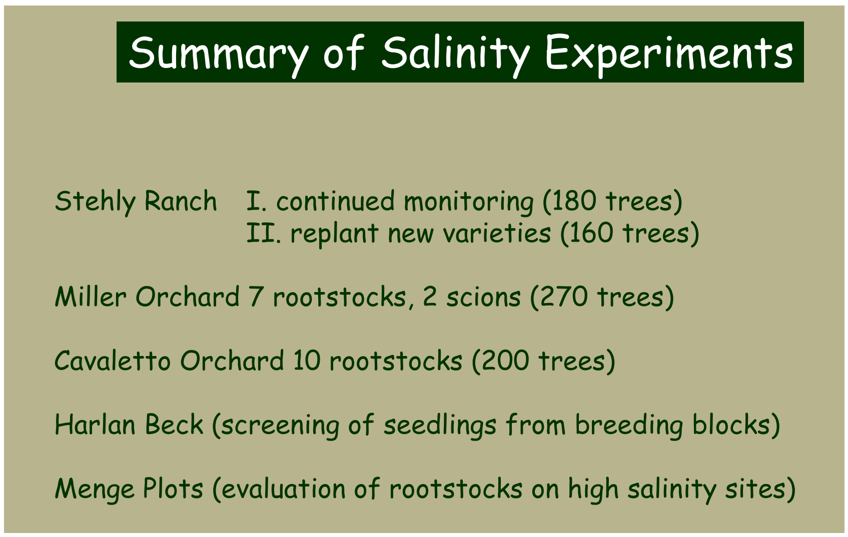

Figure 4: *Summary of salinity experiments in selected orchards conducted by Dr. David Crowley.*

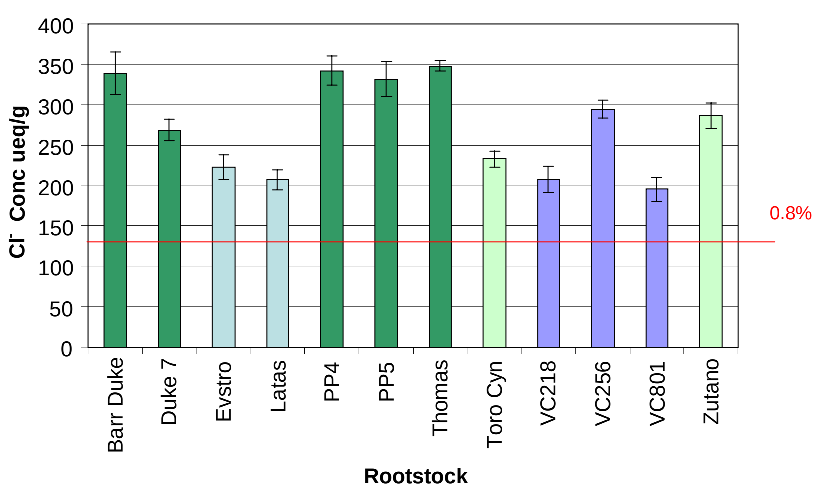

Figure 5: *Leaf chloride levels in September 2002 for 'Hass' avocado grown on different clonal rootstocks. Data from Stehly Ranch trial near Valley Center, CA. Bars shaded ▢ are rootstocks originating from the UC Riverside selection program; bars shaded ▢ are also California selections; bars shaded ▢ are rootstock selections from South Africa; and rootstocks shaded ▢ are selections from Israel.*

I can't stand up here and give you a lot of results, except from the Stehly block (Figure 5). These are leaf chloride levels of Hass on various rootstocks. The green bars are materials from the California program. Two rootstocks are from South Africa, the Evstro and the Latas. One rootstock is a selection of Toro Canyon that Mike talked about, that's from Brokaw Nursery in Saticoy, CA. The three blues bars, you can see some of them have, the VC801 in particular, very low chloride levels in the leaves, these are from Dr. Ben Ya'acov's program. And then the control for this project, is Hass on Zutano seedling. The bottom line here is we're indeed in the field, seeing a lot of variability between rootstocks in terms of chloride and also with sodium concentrations in the leaves.

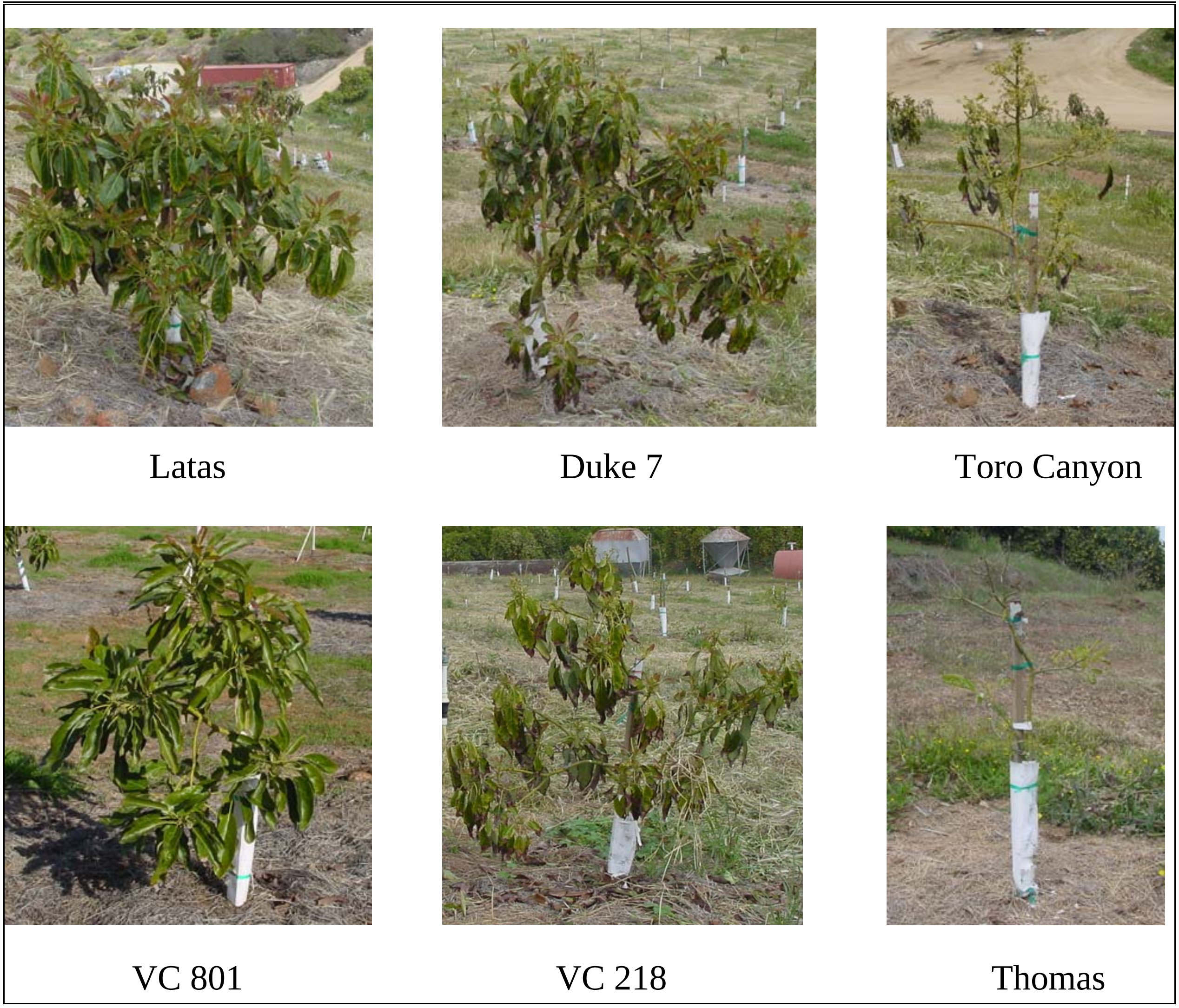

Figure 6: *Photographs of trees in the experiment at the Stehly Ranch in Valley Center, CA. Photographs taken in April 2002 and are representative of 'Hass' on the differing rootstocks. Plants showing promise are: Latas (Merensky I), Evstro (Merensky II), VC 801.*

And this is just to show you what the trees look like (Figure 66). These pictures were taken about a year ago. Here's the Latas, which is from South Africa. Duke 7, Toro Canyon, VC801 andVC218 from Israel, and Thomas. And I think the pictures say it all.

Figure 7 is just to give you a little bit more detail of the plot that has been set up in Santa Barbara. We have Hass and Lamb Hass on Uzi, which is a very promising rootstock from John Menge's program that, in very preliminary planting in high root rot and salinity conditions, seems to be very tolerant and we hope to observe in this grove.

Rootstock - Salinity Field Trial II
Established 2003
Pete Miller Orchard, Santa Barbara, CA

Hass / Uzi
Hass / Dusa
Hass / Zentmeyer
Hass / Steddom
Hass / Thomas
Hass / Latas
Hass / Toro Canyon

Lamb Hass / Uzi
Lamb Hass / Dusa
Lamb Hass / Zentmeyer
Lamb Hass / Steddom
Lamb Hass / Thomas
Lamb Hass / Latas
Lamb Hass / Toro Canyon

Figure 7: *Details of Miller plot near Santa Barbara, CA.*

Dusa is another rootstock from South Africa. Zentmyer is from the U.C. breeding program. Steddom is also from the U.C. breeding program. Thomas, you all know. Latas is from South Africa, and then Toro Canyon. In this study, the Toro Canyon and Thomas are serving as the control.

And with that, I just want to make a closing comment that we're on the road to developing salt, or identifying salt tolerant rootstocks in California, but we still have a long way to go.

Questions

[Speaker: Stephen Grattan]

Thanks Mike and May Lu. I appreciate your presentations, and I think that was very good. I think that's a good way to stimulate discussion. I wish at this point you had all the answers as to which of these rootstocks are the best candidates.

I think what I'd like to do is maybe have, one or two questions without it getting out of control, before we go on to the other presentations. Just while these presentations are more fresh in your mind. Is there any particular questions the audience would like to ask regarding these projects?

[audience member 1]: From what Mike showed; It's really in the sense that the different response of the leaf area and the photosynthesis, because, if you're talking about stress response, then you'd see the opposite. The leaf area is the first one to respond, and the photosynthesis would be the rest, because of the stomatal response. Which indicates that you don't have a responding effect from the leaf itself other than that.

[Michael Mickelbart]: Yeah, it's important to keep in mind that, again, this was a very controlled experiment, so the trees had plenty of water available. But I agree, I think, we should have seen some osmotic effects, and we saw almost none. So it definitely indicates that it's the toxic ions that are the problem.

[audience member 2]: I noticed a couple of photos where the growth is down, and I guess it's the field experiments I was looking at. It looked like the canopy structure may be slightly different. So the question is- do these salt stresses, just lower growth, or do they shift developmental age, or shift the actual canopy growth, or something more structural than just lowering the growth?

[Michael Mickelbart]: I'll let Mary Lu talk about the field observations. In our study we did look at growth patterns, looked at flushing patterns, and there was no effect of salinity on them. So the trees were developing, and the developmental stage was the same regardless of salinity level. But obviously things like photosynthesis were affected.

[Mary Lu Arpaia]: Well, the plan that Dave Crowley has at this point in time is the trees are just being planted out. We've decided to take the tact that the trees are being established with the saline irrigation water that's available. There was a lot of discussion on whether to plant the trees with good water, let them acclimatize, and then hit them with the saline water. And the ultimate was to begin the irrigation with the saline water to really see how these trees will perform under real-life conditions.

So, right now, we're in the monitoring mode, and we're not taking any physiological measurements. But I think, certainly, as these trials progress, we will be looking at a lot of these measurements with photosynthesis and other parameters. But the bottom line is production. Tree growth and production are probably going to be *the* key measurements that are going to be taken in these trials.

[Stephen Grattan]: Okay. Thanks, Mary Lu.

So what were' going to do at this point, is get a short presentation from Dr. Nirit Bernstein and Dr. Miriam Zilberstaine about some of the work they've been doing in Israel, specifically the effect of salinity on avocado root and shoot growth.