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The response of avocado to salinity and water-fertilizer management

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It's quite difficult to summarize an experiment which lasted for nine years in few minutes here. So, I'll do my best, and describe only part of the tremendous amount of data which was gathered during the years.

This experiment was conducted by Reuben Steinhardt, Dov Kalmar, who passed away about two years ago, and Yosef Shalhevet, who was also a part of this experiment. I was the only agriculturist on this project, and they were soil scientists. So I'll devote my presentation to the agricultural part of the results.

I think, that this lab in Israel is the only in the world that run field experiments on salinity. There are many experiments in pots and lyisimeters, but field experiments; I believe we are the only one. We had several field experiments. But this was the only experiment where four levels of salinity were included.

The experiment was conducted in the western Galilee where water quality is good, it contained 90 parts per million chloride in the drinking water. Then we had the treatment of 250, which is equal to the national pipeline which leads water from the north part of the country to the south. And we had about 400 - 420 ppm, which is considered, more or less, as the upper level of salinity which avocado could be irrigated with. Then we had a treatment of changing salinity (chloride level) from 250 ppm in the beginning of the season to 420 ppm at the end. And that's the situation which you usually get by pumping water from wells, which become more salinized during the irrigation season.

Parameter	Chloride concentration (mg/L)				S.E.
	90	250	250-420	420	
Cl (meq/L)	3.3 c	7.7 b	8.8 b	11.7 a	0.5
Na (meq/L)	2.8 c	6.5 b	7.1 ab	7.7 a	0.2
EC (dS/m)	1.03 c	1.40 b	1.80 ab	2.04 a	0.06
SAR	1.08 c	2.46 b	2.73 ab	2.91 a	0.13
$N\text{-}NO_3$ (mg/kg)	3.8 a	3.8 a	3.4 ab	3.0 a	0.3

Table 1. Soil characteristics at the 0 – 60-cm depths following 3 irrigation season as influenced by irrigation water salinity.

Table 1 presents the effect of these irrigation treatments on some of the soil characteristics at the research site during the 3 irrigation seasons we conducted the work. These are the averages of 0 – 60-cm soil samples. You can see the concentration of chloride which were increasing with the increased salinity, and sodium, and the electrical conductivity which runs from 1 to 2, and SAR from 1 to almost 3, and the nitrogen, which is almost equal in all treatments.

First, there was an effect on leaf burn and leaf scorching (Table 2). You can see that we had two varieties, 'Ettinger' and 'Hass' and several rootstocks, represented here only as the Mexican types compared to the West Indian group. We see that the 'Ettinger', generally, suffered more than the 'Hass'. We can see that leaf burn damage to the West Indian was relatively small, although significant even on the West Indian rootstocks. The damage on the Mexican rootstocks was quite high, with greater leaf burn as we increased the salinity.

Cultivar	Rootstock	Chloride concentration (mg/L)				S.E.
		90	250	250-420	420	
Ettinger	Mexican	0.4 c	1.6 b	1.9 ab	2.3 a	0.2
	West Indian	0 b	0.5 ab	0.5 ab	0.9 a	0.25
Hass	Mexican	0.2 b	1.3 a	1.4 a	1.8 a	0.3
	West Indian	0	0.3	0.1	0.1	0.15

Table 2. The effect of salinity and rootstock on leaf burn in the autumn (0 = no burn; 3 = severe scorching).

Rootstock	Chloride concentration (mg/L)				S.E.
	90	250	250-420	420	
Mexican	245 a	206 ab	196 ab	193 b	10.3
West Indian	333	355	335	321	6.4

Table 3. The effect of salinity and rootstock on the trunk cross-section area (cm^2) in cv. 'Hass'.

Another representation is the effect of salinity on tree growth (Table 3). We found that the trunk area is quite representative, representing well all the growth parameters of the trees which are represented here. We can see a significant decrease in the trunk cross-section area of the 'Hass' on the Mexican rootstocks, while there was no effect, or no significant effect on the West Indian rootstock.

We found out that there was a highly significant treatment effect on leaf shedding (Figure 1). Leaf shedding was much greater in the high salinity treatment than in all the others. I didn't mentioned before, in addition to the four salinity levels, we had two irrigation treatments, two water amounts: a standard one and an increased amount by 30%. The idea was to investigate if the effect of salinity can be overcome by leaching the soil. I have to tell you right now that it is quite complicated, especially when we grow avocados on heavy soils. Avocado suffers a lot from lack of soil aeration. If we increase the water amount we are causing problems, as was stated here earlier, sometimes, you get chlorosis when you increase the amount of water.

There was a very marked effect on leaf shedding, and the leaf shedding occurred right during the time of flowering and fruit set. In another research project, we found out that the avocado tree has to be covered with leaves at the time of flowering, and if leaves are dropping, productivity goes down significantly. So this leaf shedding was quite in accordance with the results we got later.

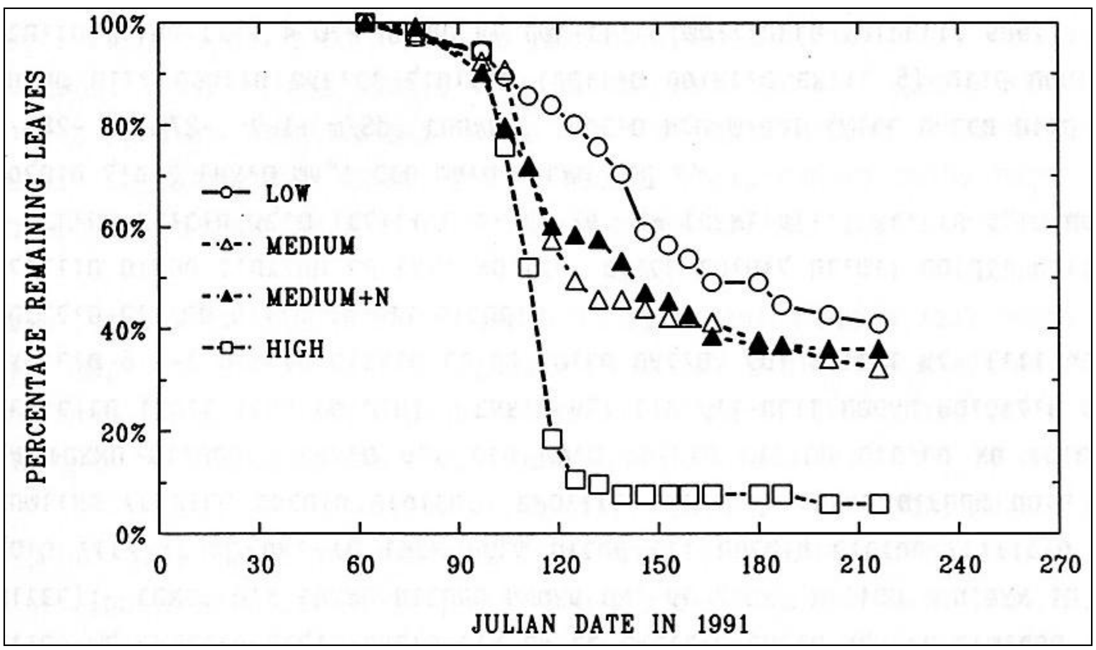
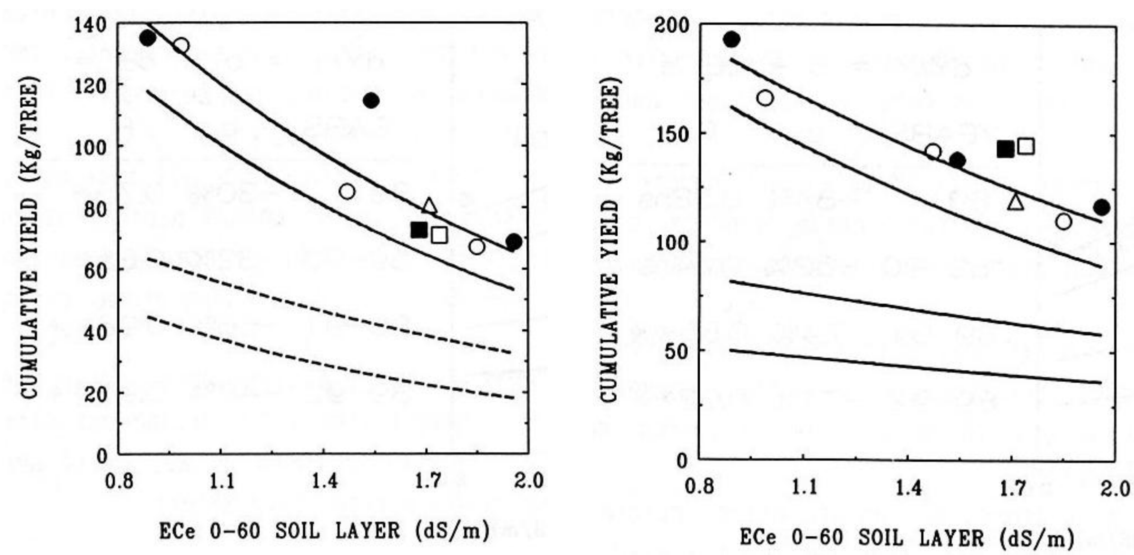


Figure 1. Leaf shedding of 'Ettinger' on Mexican race rootstocks for the 4 salinity and nitrogen treatments.

We started the experiment from the time of planting. The cumulative yield of 'Ettinger' from years 5 through 8 on two rootstocks is shown in Figure 2. In Figure 2A is the results of 'Ettinger' on Mexican rootstock. You can see that the slopes are going down with increasing salinity, which means as we increase salinity, productivity is being reduced, and you can also see that, as the years are advancing, the slope is steeper, that means we are losing more production because of the salinity.

The same results were obtained on the Ein-Harod rootstock, which is a West Indian rootstock (Figure 2B). If you think that you are safe to graft to West Indian rootstocks in order to overcome salinity, you are wrong, because also the West Indian rootstocks suffer from salinity, although to somewhat lesser extent than the Mexican.

When we compare the Mexican and the West Indian one beside the other (Figure 2) you can see that the slope of decrease in production is much steeper in the Mexican than the decrease in production in the West Indian. Generally speaking, there is 12% loss of production for every milliequivalent of chloride in the irrigation water (1 meq/L Cl = 35.5 ppm).



A. 'Ettinger'/Mexican cumulative yields *B. 'Ettinger'/Ein-Harod cumulative yields*

Figure 2. The cumulative yield (kg/tree) of 'Ettinger' on 2 rootstocks for years 5 through 8 (1989-1992). A) Mexican rootstock. B) Ein-Harod (West Indian) rootstock.

Cultivar	Rootstock	Chloride concentration (mg/L)				S.E.
		90	250	250-420	420	
Ettinger	Mexican	139 a	99 b	83 b	87 b	10.6
	West Indian	174 a	152 ab	152 ab	121 b	13.3
Hass	Mexican	116 a	95 ab	63 b	68 b	13.2
	West Indian	154 a	145 ab	139 ab	116 b	10.2

Table 4. The effect of salinity and rootstock on cumulative yield (kg/tree) for the first 7 years after planting.

In Table 4 we compare 'Ettinger' and 'Hass' on the two rootstocks. You can see a general decrease in production as we increase the salinity. You can see this in all treatments, in all rootstocks, there was a significant decrease in the 420 mg/L. In the 'Hass' on the Mexican, there was also a significant decrease by this change in concentration. Generally, the result was, the average of theses two values, that means it was somewhere between the 250 and 420. And the Mexican with the 'Ettinger', we also saw a significant decrease at the 250 mg/L as compared to the 90 mg/L of chloride.

As I mentioned earlier, in this experiment we had two more treatments (Table 5); Regular irrigation and a surplus amount of water. Generally speaking, there was no effect of the surplus amount of water as compared to the regular amount of applied water. These are the results of the first five years of the experiment, both on the Mexican rootstock, and some effect on the West Indian rootstock, but not much.

Rootstock	Irrigation regime	Chloride concentration (mg/L)			
		90	250	250-420	420
Mexican	Regular	14.4	9.9	9.4	7.8
	Surplus	16.8	13.3	9.3	9.0
	+ N		13.8		
	Average	15.6	11.6	9.4	8.4
West-Indian	Regular	21.2	16.6	17.6	17.7
	Surplus	27.8	22.2	23.6	19.8
	+ N		21.1		
	Average	24.5	19.4	20.6	18.7

Table 5. The effect of salinity, irrigation regime and rootstock on the average yields (kg/tree) 5 years after planting.

We had another treatment on top of the 250 mg/L chloride treatment where we added nitrogen, in order that the nitrogen will compete with the chlorine, I presume, Yosi Shalhevet will discuss this. Also in this case, we have seen that there was generally no effect. It was interesting that there was an effect in the first four years, but then, there was a significant decrease in yield of between 20 and 40%. So, it turned out that the addition of nitrogen didn't give any benefit at all.

The effect of salinity on fruit size (Table 6) is a long story in avocado. It's much more complicated, first because of alternate bearing, and this, by the way, is the reason why we ran the experiment for nine years, and not less. And also, as when we had more production, the fruit was smaller and vice versa. And in this case we see, in the 'Ettinger' on Mexican rootstock, there were larger fruit, and in the 'Hass' on West Indian as well, and that was because the respective trees carried less fruit, and therefore the fruit was larger. But, of course, the larger fruit does not compensate for the reduced production.

Cultivar	Rootstock	Chloride concentration (mg/L)				S.E.
		90	250	250-420	420	
Ettinger	Mexican	298 b	302 ab	297 b	322 a	5.6
	West Indian	295	293	297	300	3.2
Hass	Mexican	152	143	150	140	4.2
	West Indian	193 a	166 b	171 b	194 a	6.3

Table 6. The effect of salinity and rootstock on the fruit size (g).

I just want to summarize and tell you first, that we have found something very interesting. In the 'Ettinger' we see increase in production in the first years, in the first four years, and the general idea is that the tree gets some sort of a shock to be more productive. Just as we girdled the tree and give it a shock, or as when we prune the roots, for one reason on another, here also the roots get a shock from the salinity. And in the beginning, the production increased, but later on it very much decreased.

We made a very rough general calculation of the losses we had. Generally speaking, for each part per million of chloride, we are losing ten dollars per acre in income. So, from this point of view, you can make your calculations.

For example, if you are offered to use reclaimed water as compared with regular water, you can make the calculation how much cheaper you get this water but how much you are going to lose in production.

Generally speaking, what you have to try to do is to try to improve the water, if you can. We have to make sure that the growth of the trees will be good. Since, for each part per million of chloride increase you lose production, you have to take this into consideration, for example, when you have to apply potassium. The cheapest potassium fertilizer is potassium chloride. But you have to know that by using this fertilizer you are adding, also, chloride. So, it would be advisable to change to another source of potassium.