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SALINITY AND WATER MANAGEMENT IN AVOCADO

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What is distinctive about the avocado water and salinity relations? It may not be much except for the fact that avocado is the most salinity sensitive crop among fruit trees (especially chloride salinity) yet its response to water shortage is mild and it exhibits great variability in results. Indeed, the class A pan factor (Kp) ranges from 0.42 in June to 0.61 in October (Shalhevet et al., 1981). Similar results were obtained by Steinhardt et al,1993 were the mean Kp for the irrigation season was 0.5. For citrus, the mean Kp factor was 0.5 as well (Shalhevet et al., 1981).

Water requirement of avocado

The following production function curve (Fig. 1) was constructed using some mathematical manipulations (Steinhardt et al., 1991) and it looks good. The data points, on which it is based, are presented in Figures 2 and 3. The spread of the data is quite large resulting from year to year (weather), site to site (soil and climate), rootstock and variety, and cultural practices variations.

Figure 1

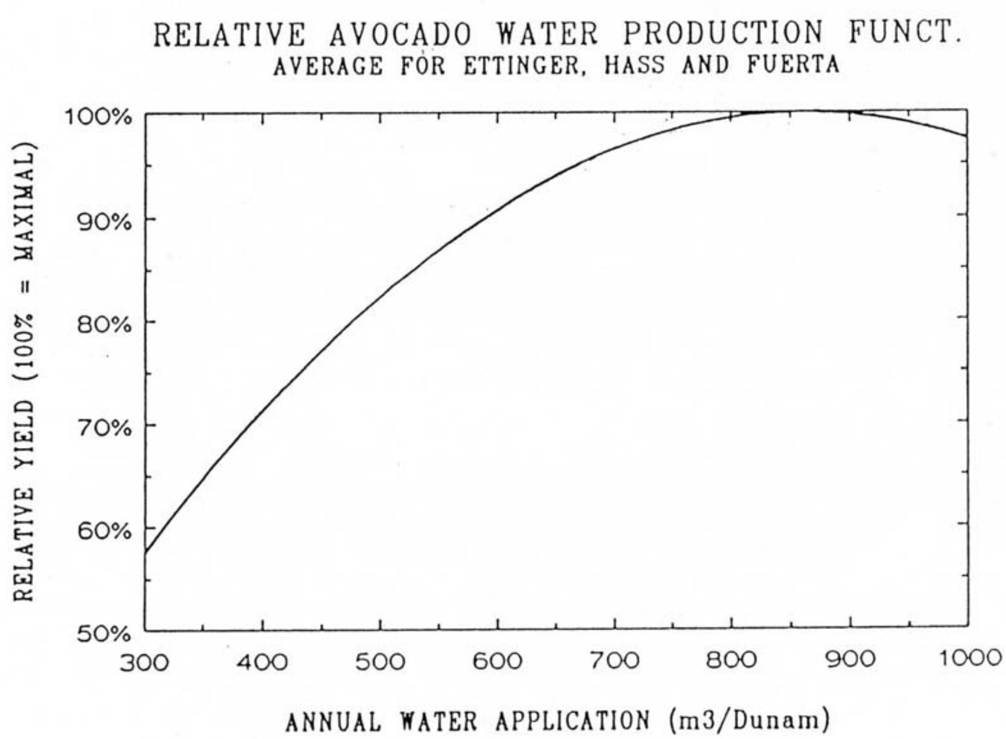
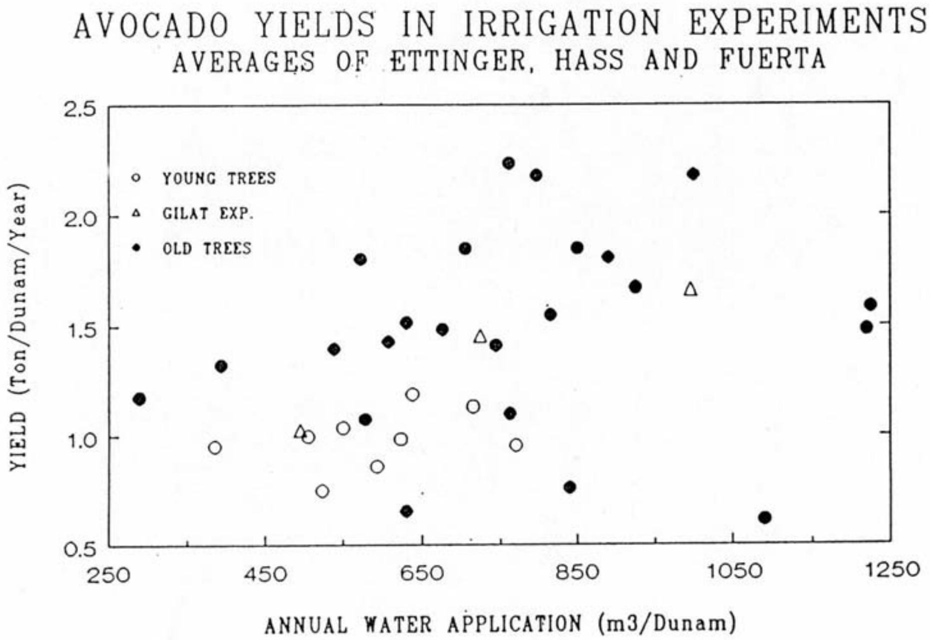


Figure 2



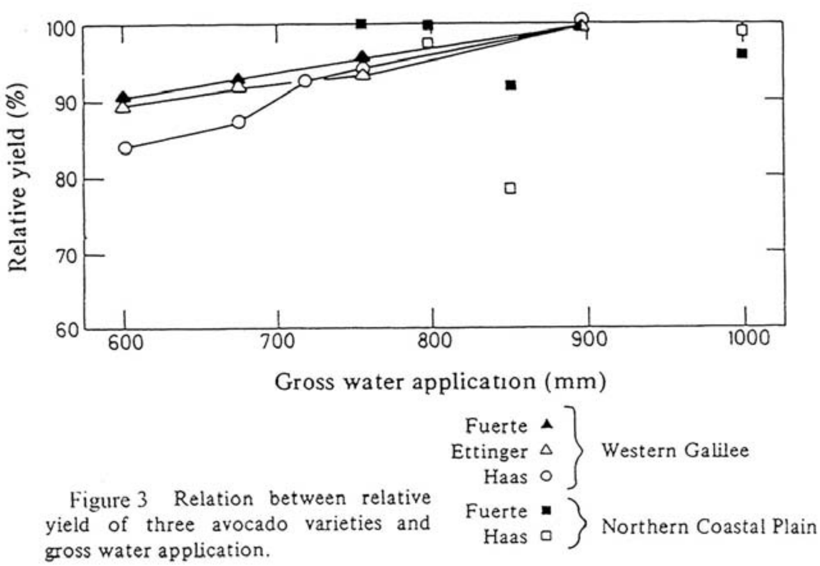


Figure 3 Relation between relative yield of three avocado varieties and gross water application.

A production function drawn from results of early experiments in Israel is presented in Figure 4 (Shalhevet et al., 1981), showing a 10% increase in yield in the range of water application between 600 and 800 mm. In addition, avocado absorbs most of its "consumptive use" water from shallow depths (60 cm) - for heavy textured soils 95% and for medium textured soils 80% (Table 1).

Table 1. Water uptake by avocado from various soil layers (as a percentage of total uptake) for the optimum treatment.

	Soil layer (cm)					
Location	**0 – 30**	**30 – 60**	**60 – 90**	**90 – 120**	**120 – 150**	**150 – 180**
Western Galilee	82	15	2	1		
Northern Coastal Plain	40	40	15	3	1	1

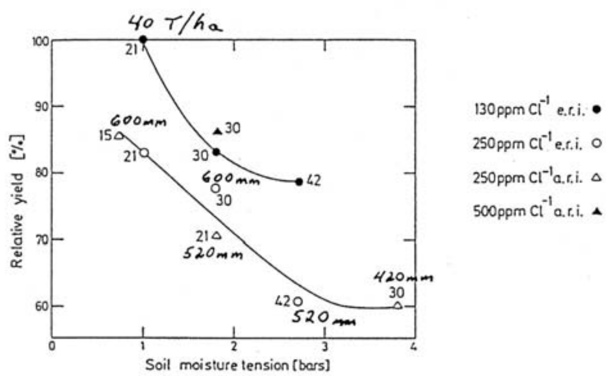


Figure 4 The relation of relative yield to mean soil moisture tension in the 30–60 cm depth interval for three levels of chloride in the irrigation water. Numbers near points indicate irrigation intervals in days

How does the avocado respond to different cultural practices related to water and salinity? For lack of much specific data for the avocado and for lack of evidence to the contrary, we will assume that the avocado will respond to some cultural techniques (e.g. irrigation methods) in similar manner to citrus and thus draw some inferences from citrus for which data is available. (Searching for the lost coin under the light ?!)

Irrigation method and water distribution in the soil

The irrigation method most prevalent in most of the avocado orchards in Israel and probably in California as well is drip or micro sprinkler. This method results in only part of the soil volume being wetted. The wetted volume depends on the irrigation method used and its design. There is a limitation as to how small the wetted volume can be without ill effects. A few experiments with citrus revealed that a minimum of about 30% is required in order to prevent restricted water uptake and yield reduction. Table 2 summarizes data from an experiment with grapefruit, which support this conclusion (Beilorai, 1982). Results of an experiment with Shamouti oranges and alternate row irrigation (a.r.i.- irrigating only half of the soil area at twice the irrigation frequency) showed this treatment to be superior to every row irrigation with the same water quantity (Heller et al., 1973). Crop response was related to mean soil matrix potential, which was higher with the a.r.i.

Table 2. Results of varying irrigation methods and frequency on yield of Grape-fruit.

Treatment	Drip, 1 line			Drip, 2 lines			Sprinkler		
Frequency (days)	3	3	3	3	3	7	14	14	21
Water applied (mm)	630	800	800	630	800	800	630	800	800
Daily ET (mm)	3	3.4	3.4	3	3.5	3.3	3.1	3.1	3.2
Yield (T/ha)	**87**	**99**	**92**	**90**	**100**	**107**	**83**	**95**	**95**
Area wetted (%)		30			40			70	

An experiment with avocado in Greece showed that less than 30% wetting volume resulted in yield decline. However, the quantity of water applied with the smaller wetting volume was only 0.3 of pan evaporation, while the optimum quantity was 0.6 pan thus confounding the effect of the restricted wetting volume (Michelakis et al., 1993).

Response of avocado trees to salinity

Figure 5 gives a schematic presentation of tree crops salinity tolerance (Shalhevet, 1994). Avocado is by far the most sensitive tree. It is specifically sensitive to chloride toxicity with some rootstocks, notably Mexican, being more sensitive than others (Guatemalan and West Indian). Haas (1928) in California was the first to report on the specific sensitivity of avocado to chloride as manifested in marginal leaf burn, while Oppenheimer (1942) in Israel reported on the differences between the various rootstocks.

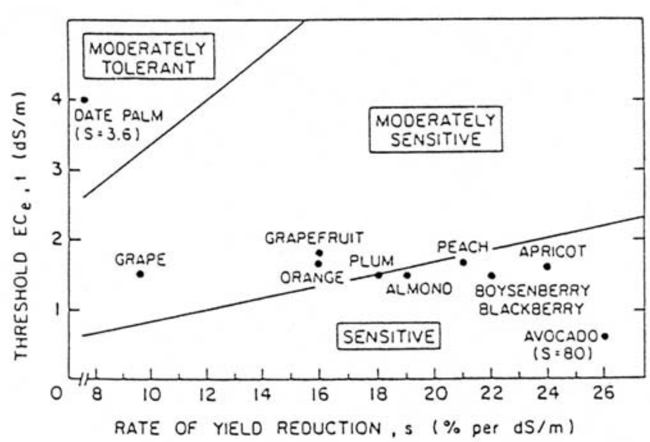


Fig. 5. Salt tolerance ratings of fruit crops (based on Maas, 1986). For explanation of *s* and *t*, see text.

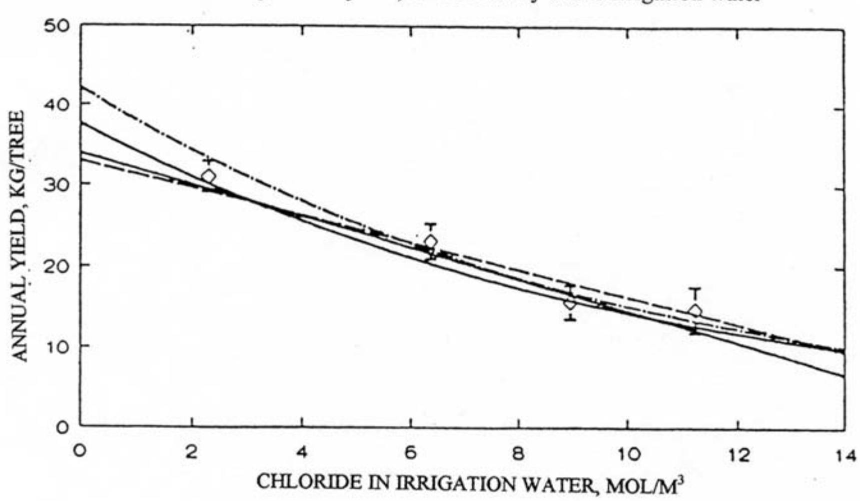
A long-term field experiment on avocado trees response to salinity was conducted in the Western Galilee region of Israel from 1984 to 1994. The experiment included four levels of salinity (80, 230, 400 and 230/400 g/m^3 chloride, the respective EC values of the water were 1.0, 1.4, and 2.0 dS/m), two irrigation quantities at all levels of salinity (90 and 110%

of recommended quantity) and an addition of 40 - 70 g/m^3 N to the normal fertigation of one of the salinity treatments (medium salinity-low water quantity) (Steinhardt et al., 1989). There were four replications; each included two varieties: 'Hass' on three West Indian and one Mexican rootstocks and 'Ettinger' on two West Indian, one Guatemalan and one Mexican rootstocks.

Following each winter rainfall the soil was leached of accumulated salts during the irrigation season. The mean salinity of the soil solution during the irrigation season was about 1.8 times the concentration of the irrigation water. Increasing the quantity of water by 20% did not result in substantial leaching during the irrigation season. On the contrary, there was some build-up in soil salinity up to mid-season (July - August) because of the greater amount of water applied containing salt. For example; in July 1990 the ECe (soil EC) of the high water application (H.W.A) was 1.34 as compared with 1.13 dS/m for the low water application (L.W.A). In August 1992 the chloride content of the soil saturation extract was 7.9 mol/m^3 for the H.W.A and only 6.7 mol/m^3 for the L.W.A. In October, however, the salinity of the L.W.A has increased to 10.1 while as a result of leaching it increased only to 8.0 mol/m^3 for the H.W.A

Figure 6

Relation of avocado yield (Ettinger and Haas on Mexican rootstock, mean of age 5 to 8 years) to the salinity of the irrigation water

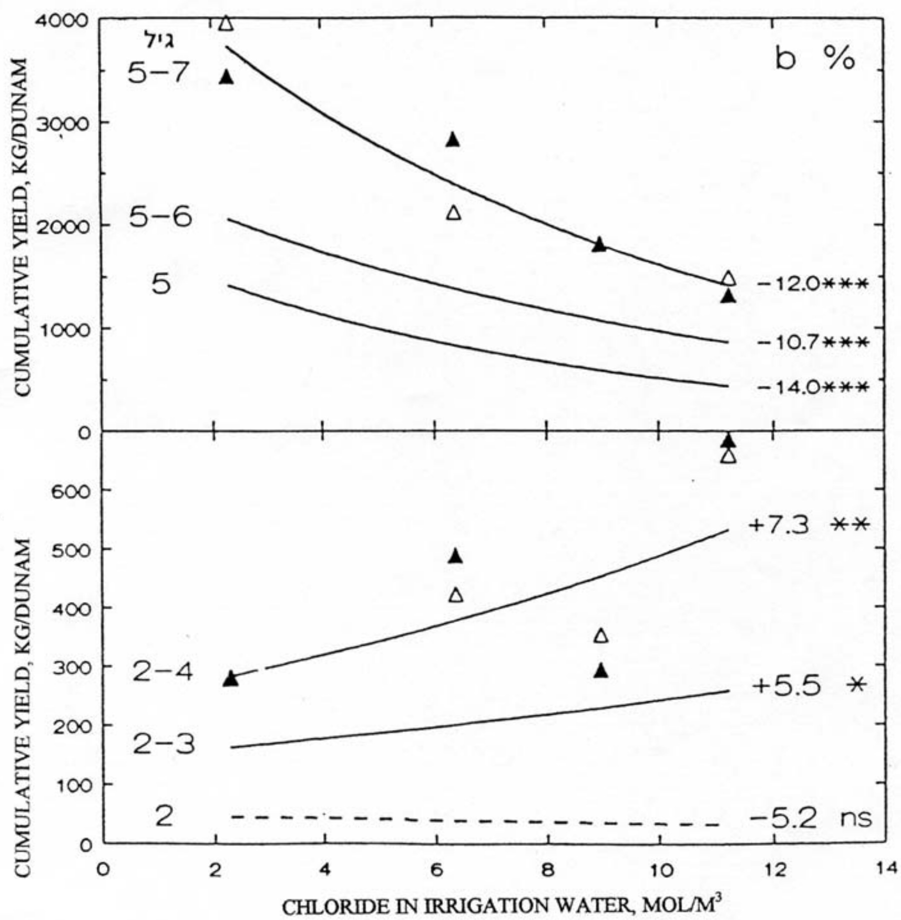


Trees grafted on Mexican rootstocks showed, as expected, higher sensitivity to salinity than those grafted on West Indian rootstocks. Figure 6 (Steinhardt et al., 1995) is a salinity production function for 'Hass' and 'Ettinger' on Mexican rootstocks mean of the last four years of the experiment (tree age 5 to 8 years). Evidently the threshold is below 70 g/ m^3 Cl (2 mol/m^3), the lowest salinity in the experiment. The slope of the line is 11.7% per mol/m^3 for established trees. For young trees the damage may be as high as 14% per mol/m^3. The treatment where the salinity at the beginning of the season was 230 g/m^3 and from mid-season to the end of irrigation it was 400 g/m^3 (treatment 230/400) did not show any particular advantage. The yield response was to the mean salinity over time. These results are in line with results obtained for many field and garden crops where the temporal mean salinity is dominant over specific stage of growth effects except for very young plants during the period of establishment (Shalhevet, 1995).

It is of interest to note the positive response to salinity of young ‘Ettinger’ trees during the tree establishment period (first 2 to 4 years). This trend is reversed after the 5th year (Fig. 7). This phenomenon may be attributed to the effect of salinity on root development and the partition of photosynthates between roots and tops. Root growth of avocado is more sensitive to salinity than top growth. With time the effect of salinity increases as salts accumulate in the roots, leaves and trunk.

Figure 7

Response of avocado yield (Ettinger on Mexican rootstock) to the salinity of the irrigation water



Salinity and nitrogen application

As noted above an extra portion of N was added to one of the treatments to determine whether or not N can reduce the damage of salinity. During the first six years of growth there was a strong positive effect of the extra N on the yield of this treatment. The effect was reversed after the sixth year resulting in a strong yield reduction (up to 40% reduction in ‘Ettinger’ and 20% in ‘Hass’). Obviously, since only one treatment received the extra N, it is not possible to determine interaction between salinity and N nutrition. Yield increase could have been obtained at all salinity levels. It is further obvious that over fertilization with N is injurious over time to avocado.

Analysis of many (51) studies of the interaction of N and salinity using many field and vegetable crops (Shalhevet, 1994) showed, by and large, that added nitrogen does not reduce the damage due to salinity. About 45% of the experiments showed the same response to salinity at all levels of N and 45% showed greater salinity damage at high than at low levels of N. Only 10% of the experiments showed reduced salinity damage at high N levels (Table 3). It is unlikely, therefore that increased nitrogen fertilization will have greater effect on avocado at higher salinity than at lower salinity even over the short run, but certainly not over the long run.

Table 3. Summary of plants to fertilizer with salinity.

Crop	**Fertilizer**	**Response to fertilizer as salinity increases (number of experiments)**			
		Total Number	**L**	**S**	**G**
Barley	N, P, K	3	1	2	
Beans	N, P, K	4	3	1	
Corn	N, P, K	6	3	3	
Cotton	N, P, K	3	3		
Grasses	N	4	2	2	
Melon	N	1	1		
Pea	N, P	2		1	
Peanuts	P	1			
Pepper	N	2	1	1	1
Rice	Zn	1	1		1
Sesame	P	1		1	
Sorghum, Millet	N, P	3		2	1
Spinach	N	1	1		
Sunflower	Fe	1	1		
Tomato	N, P	3		2	1*
Vegetables	N	6	2	4	
Wheat	N	9	4	4	1
Total		51	23	23	5

L = Lower response to fertilizer as salinity increases; S = Similar response to fertilizer at all levels of salinity; G = Greater response to fertilizer as salinity increases.
Vegetables = Lettuce, beet, onion, carrot, broccoli, cabbage
* = Fertilizer applied foliarly.

Summary of results

Table 4 summarizes the relationship of yield to the salinity of the irrigation water for the three main varieties on the various rootstocks (Steinhardt et al, mimeo) Salinity resulted in reduced tree vigor and poor seedling establishment of varieties grafted on Mexican rootstocks, but not of varieties grafted on West Indian rootstocks. Leaf burn was apparent in the fall in the former resulting in leaf drop in the spring during fruit set. No leaf burn was apparent on varieties grafted on West Indian and Guatemalan rootstocks, which had about a third chloride content of that on Mexican rootstocks.

Table 4. Maximum permissible chloride level in the irrigation water in g/m^3 for avocado varieties on selected rootstocks.

All varieties on Mexican rootstocks	100
'Ettinger' on VC28	180
'Hass' on VC28 or VC66	250
'Fuerte' on VC65	350

VC = vegetative clone (rootstock)

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