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RE-EVALUATION OF IRRIGATION WATER AMOUNTS UNDER CHANGING GROWING CONDITIONS OF AVOCADOS IN ISRAEL

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Water shortage in Israel, enforces increased efficiency (agricultural and economic) in the use of irrigation water in avocado plantations. During the last 45 years data were collected from numerous experiments (in the coastal area of Israel when irrigation water quality was 40-200 mg Cl L^{-1}) in order to evaluate the response of avocado trees to irrigation water amounts. Yields were analyzed by Steinhardt (1991) and two ranges of response to water were determined:

- 250-600 mm (in addition to 600 mm of rain)

The yield response to water in this range is constant and significant. Average yield loss is 1.57 t/ha for every 100 mm irrigation water reduction.

- 600-800 mm (in addition to 600 mm of rain)

Yield response is constant but small. Average loss is 0.33 t/ha for every 100 mm irrigation water reduction.

This yield analysis indicated that in the coastal area, 600 mm is the critical point in which below it, a damage to the tree and yield occurs. Water amounts may vary according to local growing conditions, soil type, irrigation system and yield.

The general tendency during the recent years in the Israeli avocado plantations is to increase water amounts. This approach is based on the effect of water on increased tree and fruit growth (Lahav and Kalmar, 1991, Kalmar and Lahav, 1977). These effects were repeated in almost every experiment conducted in avocado. The significance of increased water amount in avocado is important, especially in cv. 'Hass', which yields small fruit. Such fruit is either disqualified from export or sold for half price. The relationship between water amount and fruit size was not calculated yet since the major factor affecting fruit size is yield and such calculation must include single trees because of their variability in production. It should be emphasized that as with other growth factors, excess of water may induce decreased yield and fruit size, especially in plantations grown on clay soils with reduced aeration (Adato and Levinson, 1986).

Growth retardants

The use of growth retardants induce significant increase in production of medium yielding avocado plantations. Since every change in agro-technique necessitates changes on other practices used, we have tested the relationship between water and growth retardants.

The experiment was conducted in avocado plantation, planted in 1984 in the Western Galilee of Israel. Planting was on ridges with micro-jets irrigation. The cultivars were 'Ettinger' and 'Hass' grafted on Guatemalan and West-Indian rootstocks. The experiment included four replications of 12 trees each in randomized blocks. Two factors were tested:

Water amount: Four amounts: 85%, 100% (commercial), 115% and 130%. The basis was the amount recommended by the Extension Service (100%).

Growth retardants: With or with no growth retardant.

Water amounts and fertilizers applied are presented in Table 1. Fertilizers were applied in constant concentration, therefore quantities were increased in parallel to the increase in water amounts.

Table 1. Average water and fertilizer quantities applied during 5 years

	Relative water amount (%)			
	85	100	115	130
Water (mm)	530-800	610-990	710-1200	800-1430
N (kg/ha)	164-266	186-331	215-399	230-477
P_2O_5 (kg/ha)	60	75	90	107
K_2O (kg/ha)	164-235	186-292	215-352	230-420

Trunk circumference
This parameter expresses accurately the general tree growth.
Effect of water amount was not uniform in the two cultivars. A gradual, non significant increase in trunk growth was measured in 'Ettinger' with the increase in water amount (Table 2). In 'Hass', the smallest growth was measured when 85% of water was applied and the largest growth was with the commercial amount (100%) applied. Increased amounts of 115% and 130% induced reduced trunk growth and indicated a negative effect.
Effect of growth retardant – No effect on trunk circumference was measured.

Table 2. The effect of water amount and growth retardant on the annual increase (%) in trunk circumference (5 yrs avg.)

	Growth retardant	Relative water amount (%)				S.E. (Water)	Avg.	S.E. (Gr. R)	Sig.
		85	100	115	130				
Ettinger	+	2.4	4.2	3.8	4.2	0.55	3.7	0.28	N.S
	-	3.8	2.8	3.8	3.7		3.5		
	Avg.	3.1b	3.5ab	3.8a	3.9a	0.39	3.6		0.049
Hass	+	2.8	4.3	4.4	3.4	0.55	3.8	0.28	N.S
	-	3.0	5.1	3.2	3.2		3.6		
	Avg.	2.9b	4.7a	3.8ab	3.3ab	0.39	3.7		0.027

Fruits per tree
A significant effect was measured in cv. 'Ettinger' (Table 3). Increased water amount reduced fruit number/tree. The effect on the sprayed trees was more significant than on the non sprayed ones. The six years average showed that increasing water amount from 100% to 130% reduced the number of fruits by 52 fruits/tree in the sprayed 'Ettinger' trees while only 10 fruits/tree were reduced in the unsprayed control trees. In the sprayed trees even 15% increase in water amount reduced the number of fruits significantly. Water amount had almost no effect on 'Hass' trees. Reducing water amount from 100% to 85% had no effect in both cultivars.

Table 3. The effect of water amount and growth retardant on the number of fruits/ tree (5 yrs avg.)

Cultivar	Growth retardant	Relative water amount (%)				S.E. (Water)	Avg.	S.E. (Gr R)	Sig.
		85	100	115	130				
Ettinger	+	190.0a	176.8a	120.9b	125.2b	13.9	153.2	6.9	0.040
	-	154.7	144.6	181.5	135.0		154.0		
	Avg.	172.4a	160.7ab	151.2ab	130.1b	9.8	153.6		0.040
Hass	+	280.3	277.6	264.5	256.7	18.2	269.8	9.1	N.S.
	-	260.5	263.0	294.1	292.0		277.4		
	Avg.	270.4	270.3	279.3	274.4	12.9	273.6		N.S.

Fruit size

Fruit weight was calculated according to the size grading in the packing house. However, no statistic analysis was done due to lack of replications. Therefore, the results show only tendency.

Effect of water amount- increasing water amount up to 115% increased fruit weight in both cultivars (Table 4). Additional water increase did not result in fruit growth. Increasing water amount from 85% to 100% increased 'Ettinger' fruit weight by 1.5g and 'Hass' by 2.9g. Additional increase of water amount to 115% added 7.9g to 'Ettinger' fruit weight and 3.2g to 'Hass'.

Effect of growth retardant – The six years average showed a 5.5g increase in fruit size in 'Hass' resulting from the growth retardants but no effect on fruit size in 'Ettinger' was recorded

Table 4. The effect of water amount and growth retardant on fruit weight (g) (5 yrs avg.)

Cultivar	Growth Retardant	Relative water amount (%)				Avg.
		85	100	115	130	
Ettinger	+	282	284	296	291	288.4
	-	287	288	292	289	289.1
	Avg.	285	286	294	290	288.7
Hass	+	197	204	205	205	202.7
	-	197	197	201	197	197.8
	Avg.	197	200	203	200	200.2

Yield

Yield was calculated according to the fruit number/tree and fruit size (Table 5).

Effect of water amount- The main effect was on fruit number. The highest six years average in 'Ettinger' was recorded in the lowest (85%) water amount and the lowest in the trees irrigated with the commercial quantities. Though the lowest fruit number was counted in the trees irrigated with the highest water amount, their fruit weight was somewhat larger and compensated for the reduced number of fruits (compare tables 3 and 4). Water amount had no significant effect on the yield of 'Hass'.

Effect of growth retardant – No effect was recorded in both cultivars.

Table 5. The effect of water amount and growth retardant on the yield (t/ha) (5 yrs avg.)

Cultivar	Growth retardant	Relative water amount (%)				S.E. (Water)	Avg.	S.E. (Gr. R)	Sig.
		85	100	115	130				
Ettinger	+	14.5	11.4	12.1	14.6	1.12	13.1	0.59	N.S.
	-	13.8	10.0	13.0	10.8		11.9		
	Avg.	14.2a	10.7b	12.6ab	12.7ab	0.83	12.5		0.058
Hass	+	15.0	14.8	14.1	16.5	0.82	15.1	0.41	N.S.
	-	15.5	14.9	15.3	16.2		15.5		
	Avg.	15.2	14.8	14.7	16.3	0.58	15.3		N.S.

Salinity

Due to increased use of marginal and brackish water for irrigation in Israel, salinity may affect the Israeli avocado production. The sensitivity of avocado trees to salinity is known from the twenties in California (Haas,1928). The higher sensitivity of the Mexican race as compared to the West-Indian was found in Israel in the thirties. Information on the response of avocado to salinity is needed to predict the damage due to an increase in salinity of irrigation water. Quantitative data from field experiments is difficult to get especially in avocado because of its alternate bearing habit.

An experiment of the effect of irrigation water salinity in the range of 80-400 mg Cl L^{-1} was therefore studied with 'Hass' and 'Ettinger' trees on Mexican and West Indian rootstocks on clay soil. Four salinity levels were tested: Low- 90 mg Cl L^{-1}, Medium- 250 mg Cl L^{-1}, Medium-High- 250-420 mg Cl L^{-1} and High- 420 mg Cl L^{-1}. In addition two approaches to overcome salinity damage were tested: leaching and increasing nitrogen fertilization.

Increasing salinity resulted in annual increase in chloride and Ca+Mg and in a long term increase in sodium in the soil (Table 6). Soil nitrate decreased with the increase in salinity.

Table 6. Effects of irrigation water salinity on some soil parameters in 0-60 cm layer during 3 irrigation seasons.

Parameter	Chloride concentration (mg L^{-1})				S.E.
	90	250	250-420	420	
Cl (meq L^{-1}L)	3.3 c	7.7 b	8.8 b	11.7 a	0.5
Na (meq L^{-1})	2.8 c	6.5 b	7.1 ab	7.7 a	0.2
EC (dS m^{-1})	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-NO_3 (mg kg^{-1})	3.8 a	3.8 a	3.4 ab	3.0 b	0.3

As expected, salinity accelerated much the rate of leaf burns (Table 7). The effect on the trees grafted on the Mexican rootstock was much greater than that on those grafted on West Indian.

Table 7. The effect of salinity and rootstock on leaf burns in the autumn (0 - no burns; 3 - sever scorching)

Cultivar	Rootstock	Chloride concentration (mg L^{-1})				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

The effect of salinity on leaf shed was analyzed by Porat et al. (1992). It was clearly demonstrated that the leaves of the ‘Ettinger’ cv. were shed about two weeks before ‘Hass’ and that the intensity of leaf shed was parallel to the increase in salinity level (Fig. 1) and also to the level of Cl in the leaves. It is suggested that salinity damage might be decreased by reducing leaf shedding in the spring possibly by improving fertigation.

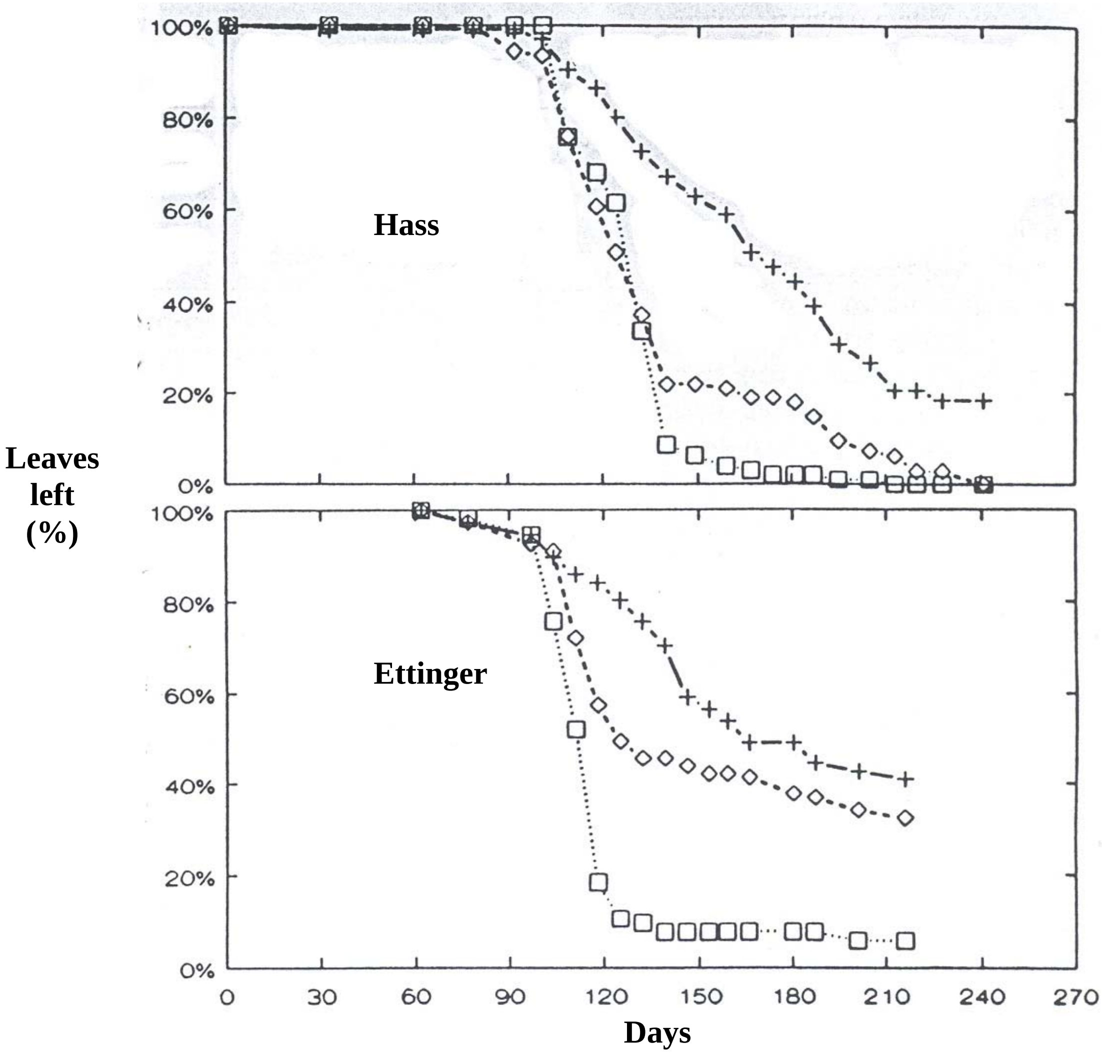

Fig. 1. The effect of salinity level on leaf drop

It was clearly demonstrated that salinity impairs the production of avocado trees even if grafted on West Indian rootstocks (Table 8). However the reduction in yield was greater on trees grafted on Mexican rootstock (-38% and –42% in 'Ettinger' and 'Hass' respectively) as compared to those grafted on West Indian (-30% and –20%).

It was interesting to note that salinity had a positive effect on yield in 'Ettinger' during the first four years. This effect of salinity may be explained on the basis of damage to the roots which is parallel to the effect of girdling, a tool for inducing productivity in young trees (Lahav *et al.*, 1986). It corresponds also to the results of Downton (1978) who found increased flowering in avocado as a result of salinity.

Table 8. The effect of salinity and rootstock on cumulative yield (kg/tree) for the first 7 years after planting.

Cultivar	Rootstock	Chloride concentration (mg L^{-1})				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

The effect of salinity on fruit size was difficult to assess. As expected the number of fruits/tree was the major factor affecting fruit size. Relatively large fruit was found in trees irrigated with highest salinity water due to their reduced yield (Table 9).

Table 9. Effect of salinity and rootstock on fruit size (g).

Cultivar	Rootstock	Chloride concentration (mg L^{-1})				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	133 a	166 b	171 b	194 a	6.3

Leaching had some positive effect on the yields especially in the low level of salinity (Table 10). These increased amounts of water did not leach chlorides from the soil, as expressed also by their level in the leaves, because of the heavy clay soil. Lack of aeration resulted in damage to avocado roots, reduced water uptake and increased salinity damage. Increasing water amounts increased also soil SAR and iron induced chlorosis. Similar results were found in another experiment in the same soil when water was added to the trees in the spring, when the soil was already saturated from winter rainfall (Lahav and Kalmar, 1982). Adding nitrate nitrogen, to compete with the chlorides, showed no effect at all under the above mentioned conditions.

Table 10. Effect of salinity, irrigation regime and rootstock on the average yields for 'Ettinger' and 'Hass' (kg/tree) 5 years after planting.

Rootstock	Irrigation regime	Chloride concentration (mg L^{-1})			
		90	250	250-420	420
Mexican	Regular	14.4	9.9	9.4	7.8
	Leaching	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
	Leaching	27.8	22.2	23.6	19.8
	+ N		21.1		
	Average	24.5	19.4	20.6	18.7

The effect of water on post harvest

There is very little information on the subject, though indirect information exists.

It was proved in many field experiments that water is increasing fruit size and hence affects harvest date. The effect on harvest date is based on the effect of fruit size on oil content, but there is also a tendency for a direct effect of water on oil content.

Oil content was determined in fruits of uniform size harvested from trees of uniform yield (Lahav and Kalmar, 1977). It was demonstrated that increased water amount (achieved by reduced irrigation intervals) increased oil content in 'Ettinger' and 'Fuerte' avocados (Table 11). Thus, our assumption is that it may be possible to advance somewhat the harvesting date by frequent irrigations which increase the oil percentage and fruit size.

Table 11. Effect of water amount (and irrigation interval) on avocado fruit oil content (%)

Cultivar	Fruit weight (g)	Water amount (mm) and irrigation interval (days)				S.E.	Sig.
		889 (7)	745(14)	668(21)	594(28)		
Fuerte	445	14.6	16.9	15.3	15.2	1.02	N.S.
	364	16.3	15.8	15.3	14.5	0.56	0.05
	261	14.8	15.2	15.5	13.5	0.43	0.05
Ettinger	298	10.7	10.3	9.4	9.9	0.23	0.01
	277	10.4	10.0	10.1	9.3	0.17	0.01
	234	9.0	9.5	8.9	9.2	0.22	N.S.

Irrigation can potentially affect disorders. Bower and van Lelyveld (1985) found that different irrigation schedules altered the activity of polyphenol oxidase in harvested fruit. According to Arpaia and Eaks (1990), irrigation management did not appear to significantly impact the rate of flesh softening, but there was a significant difference in the percentage of fruit with internal breakdown after 6 weeks in storage. Fruit harvested from trees irrigated at 80% Etc had significantly less internal breakdown as compared to either the 100% or 120% Etc treatments.

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