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THE VALUE OF PHYSIOLOGICAL INDICATORS IN DETERMINING THE IRRIGATION REQUIREMENTS OF THE AVOCADO TREE[0]

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Introduction

Within the context of an experiment designed to clarify the irrigation requirements of the avocado tree in the Western Galilee in Israel (1), physiological indicators, such as tree and fruit growth, were evaluated for their suitability in the planning of irrigation regimes.

Trunk and fruit growth rates have been used previously as indicators for fruit tree irrigation requirements (6). Several workers have described the growth patterns of the trunk or the fruit, but few have compared the growth pattern with the diurnal contractions of these two plant parts (3).

Schroeder (3) showed that the avocado tree-trunk and fruit possess growth patterns characterized by diurnal expansion and contraction. The expansion is greatest in the morning while maximal contraction occurs in the afternoon, when evaporation and plant water loss are at their greatest.

One of the first reports to examine the possibility of using physiological indicators to ascertain the irrigation requirements of avocado indicated that the measurement of diurnal contractions was superior to that expressing the average growth rate of the trunk. It was also found that under the irrigation regimes tested, the growth rate of the fruit was not affected (4).

Data and Methods

The experiment consisted of four irrigation treatments, each with five replications of nine trees (three each of Ettinger, Fuerte and Hass) in randomized blocks, with two rows of guard trees between replications.

During the summer season 7-, 14-, 21- and 28-day irrigation intervals were compared. In order to prevent damage to fruit set resulting from insufficient soil moisture, the first few irrigations in the spring were with short intervals in between, and gradually increased.

During the summer of 1969 trunk diameter was recorded twice a week. The measurements were carried out in an East-West direction, using a micrometric caliper, calibrated in hundredths of a millimeter — between two brass discs attached to the trunk with plastic glue. Each tree was measured at the same time at each date.

During August and September 1970, trunk measurements were taken twice daily, in the morning and at noon. In this manner it was possible to calculate the daily trunk contraction.

Using a similar type of caliper, the growth of Hass fruit was also recorded. For this purpose discs were attached to the fruit at the points of greatest diameter. Five fruits chosen on the north side of the tree at a height of 1.5 m, were measured in each plot (25 from each treatment). Measurements were earned out twice a week during summer 1969, and daily during August-September 1970.

Results

For all three cultivars, the 1969 trunk measurements showed considerable similarity; for brevity, the results of the Hass cultivar only will be described. The trunk growth rate was affected more by yield than by the irrigation treatment applied (Fig. 1).

When trees of equal yield were compared, it was found that the greatest growth occurred in the 7-day interval treatment and the least in the 28-day treatment. Growth rates for the 14- and 21-day treatments were similar. With the onset of the rains in autumn, an increase in the growth rate occurred in the 21- and 28-day treatments.

Increasing irrigation intervals resulted in a slower rate of trunk growth in 1970. A comparison of trees with varying yields, showed that the growth rate of trees in an off-year was far above that of those in an on-year (Fig. 2). There was little difference in the trunk growth rate of trees bearing equally heavy crops under different irrigation regimes. Trees of low yield, however, showed great variation between treatments and the growth rate was inversely related to the irrigation interval. It should be noted that in all treatments growth ceased or even became negative in the day or days preceding an irrigation.

Trunk diurnal contractions, as calculated from the morning and noon trunk diameters, increased gradually from the time of irrigation. The irrigation interval was found to have a greater effect on contractions than the climatic conditions as expressed by the evaporation from a Class "A" pan. The greatest contractions occurred in the 28-day treatment previous to irrigation, and the smallest immediately after irrigation in the same treatment. The 7-day treatment showed only small differences before and after irrigation (Table 1).

The highest fruit growth rate in 1969 was measured in the 7- and 21-day treatments (Table 2), and the smallest in the 28-day treatment, in spite of its low yield. Fruit growth usually ceased a few days prior to irrigation. With the onset of autumn rains the 28-day fruit exhibited a substantial increase in growth rate compared with the other treatments.

During the period of daily measurements made in 1970 the total growth of fruit on off-year trees was almost double that of fruit on on-year trees (Fig. 3). Growth on trees with heavy yields stopped in all treatments before irrigation, whereas no growth stoppage occurred in off-year trees even in the 28-day treatment. Even under the 7-day regime the fruit growth rate on high-yielding trees was low.

A comparison between the trunk and fruit growth values for the end of summer is shown in Figure 4. The values are expressed as percentages of the 14-day-treatment growth rate, since this appears to be the most promising of the four after the first three years of experimentation (1). It can be seen that the irrigation interval affects fruit growth less than trunk growth.

A good correlation was found between trunk contraction the day before irrigation and fruit size (Fig. 5). Increasing the irrigation interval resulted in greater trunk contraction and lower fruit weight. The amount of fruit on the tree clearly affected the diurnal contractions of the trunk and also the fruit growth. On-year trees were more sensitive to lack of moisture than were off-year trees.

Smallest trunk contraction occurred immediately following irrigation, but as water stress developed contraction rapidly increased. Between irrigations, off-year trees in the 7-day treatment evinced only small diurnal contractions, whereas on-year trees contracted considerably after the fourth day.

Tree yield was inversely related to fruit growth. In the summer of 1970, fruit on heavily laden trees stopped growing in the 7- and 14-day treatments after 5 and 12 days, respectively, whereas fruit on low-yielding trees continued to grow.

Discussion

Verner *et al.* (6) found that apple tree trunk growth measurements were preferable to fruit measurements. Urielli came to the same conclusion with avocado (4). We found that, after the fruit had completed its period of intensive growth, its growth rate was the last parameter to be affected by the irrigation regime. The effects of the summer irrigation regimes on the growth of fruit and trunk, were reduced following the onset of rain in autumn. The increased soil water supply and the still high autumn temperatures induced the highest growth rate in the drier treatment. The faster growth rate of trees in the drier treatments the day after irrigation also found expression in the low contraction rate for the same day, as compared with trees irrigated at shorter intervals.

Trunk growth of heavily laden apple trees was much less than that of trees with low yields (6). Avocado fruit on heavily laden trees has also been found to grow slowly (2). The present experiment also demonstrated the difference between high — and low — yielding trees in their relative growth rates for trunk and fruit. Trunk growth was several times greater in off-year than in on-year trees (Fig. 4). Trunk growth rate, in addition, was affected sooner by the various regimes when there was a heavy crop on the tree, as compared with trees with light crops.

In an almond tree irrigation experiment, trunk growth was affected by moisture availability before being affected by the crop (5). In the case of the avocado, however it would appear that the crop effect is far greater than the irrigation regime effect.

During three years of experimentation the final fruit size was found to be noticeably affected by the various irrigation regimes (1). From the commercial point of view, Ettinger and Fuerte trees frequently produce fruit which is too large and thus unsuitable for export. There is a correlation between fruit size and trunk diurnal contraction. Fruit weighing 290 grams (considered the ideal for export) was found to be related to a trunk contraction of 25/100 mm the day before irrigation. Such a contraction was found in the

28-day regime. Hass trees frequently suffer from excessive fruit set, resulting in many fruits being less than export size (2). An ideal export size for Hass is 235 grams, and this is related to a trunk contraction of 8/100 mm the day before irrigation; such a contraction is obtained with the 7-day irrigation regime. However, it must be emphasized that trunk contraction is only one of many parameters associated with avocado fruit size (2).

The small-sized fruit on heavily laden trees in the 7-day plots (Fig. 3) might have been due to the influence of irrigation treatment on root spread in addition to the high yield. In the 7-day plots a high percentage of roots was found in the upper layers of the soil, which dry out quickly even when irrigated frequently (1).

Conclusions

The present findings must be considered as preliminary. It is necessary to emphasize that the results presented are based on one, or at most two, measurements per day. It is important to investigate the effect of the irrigation regime on fruit growth and contraction in the period immediately following fruit set, preferably with automatic continuous recording equipment. The connection between fruit and trunk measurements, irrigation regime and climatic conditions, remains to be further clarified.

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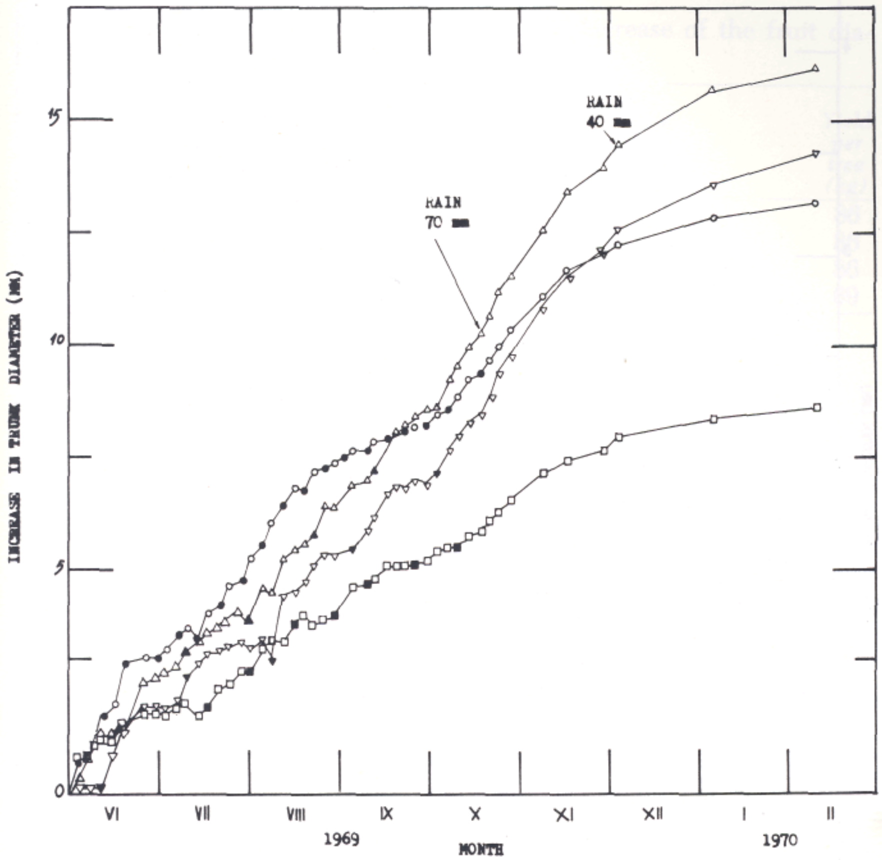
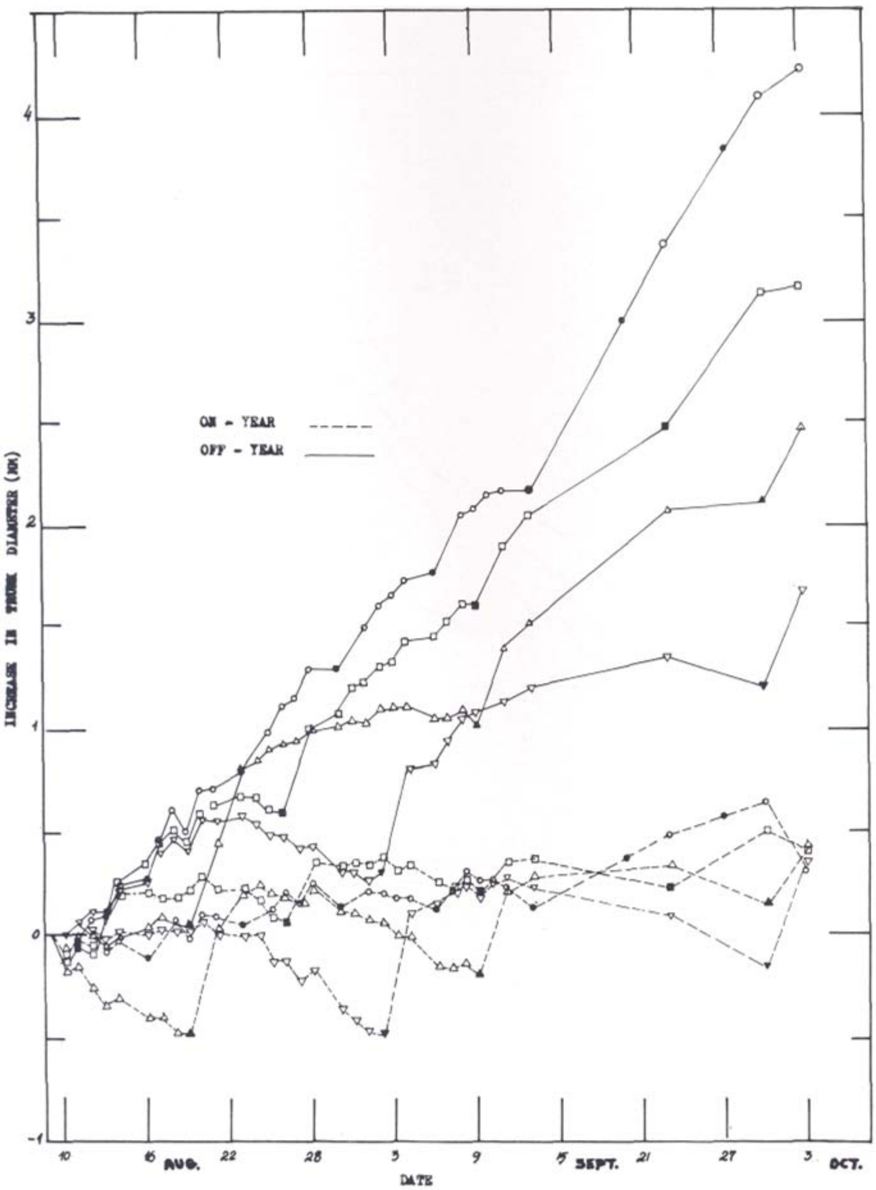


Figure 1. The effect of irrigation interval on changes in avocado trunk diameter (cumulative). Each curve represents an average of five trees.

TABLE 1. Average daily trunk contraction (mm) of avocado trees

Irrigation interval (days)	7	14	21	28
Day before irrigation	0.255	0.297	0.300	0.345
Day after irrigation	0.174	0.169	0.094	0.064

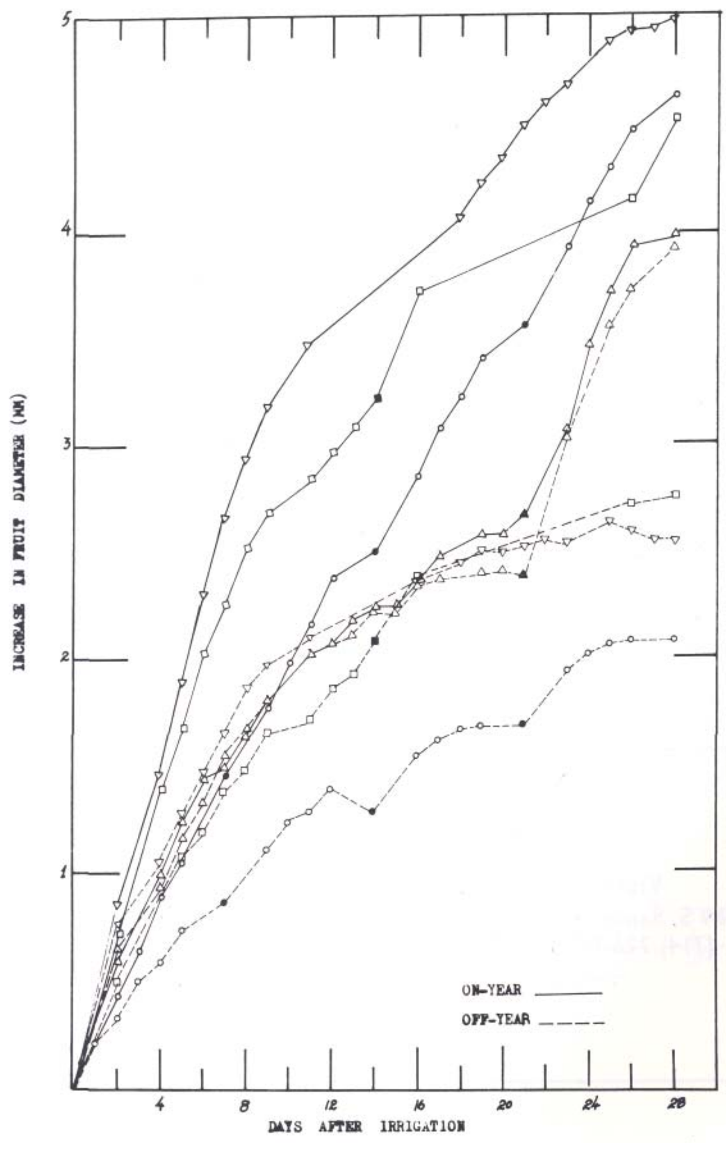


IRRIGATION INTERVAL (DAYS)	MEASUREMENT		OFF-YEAR		ON-YEAR	
	ON IRRIGATION DAY	ON OTHER DAYS	NO. OF FRUITS MEASURED	AVERAGE YIELD (KG/TREE)	NO. OF FRUITS MEASURED	AVERAGE YIELD (KG/TREE)
7	●	○	13	14	2	155
14	■	□	8	10	6	136
21	▲	△	6	63	7	120
28	▼	▽	4	60	9	132

Figure 2. The effect of irrigation interval and fruit yield ('on-year', 'off-year') on changes in the trunk diameter of avocado trees (cumulative).

TABLE 2. Effect of irrigation interval on the increase of the fruit diameter of equal-yielding avocado trees.

Irrigation interval (days)	*Increase in diameter during July-February (mm)*	*Increase in diameter during rainy season, (mm) Mid-Oct.-February*	*Yield per tree (kg)*
7	28.3	0.52	86
14	21.4	0.54	86
21	27.4	0.51	86
28	19.0	0.62	69



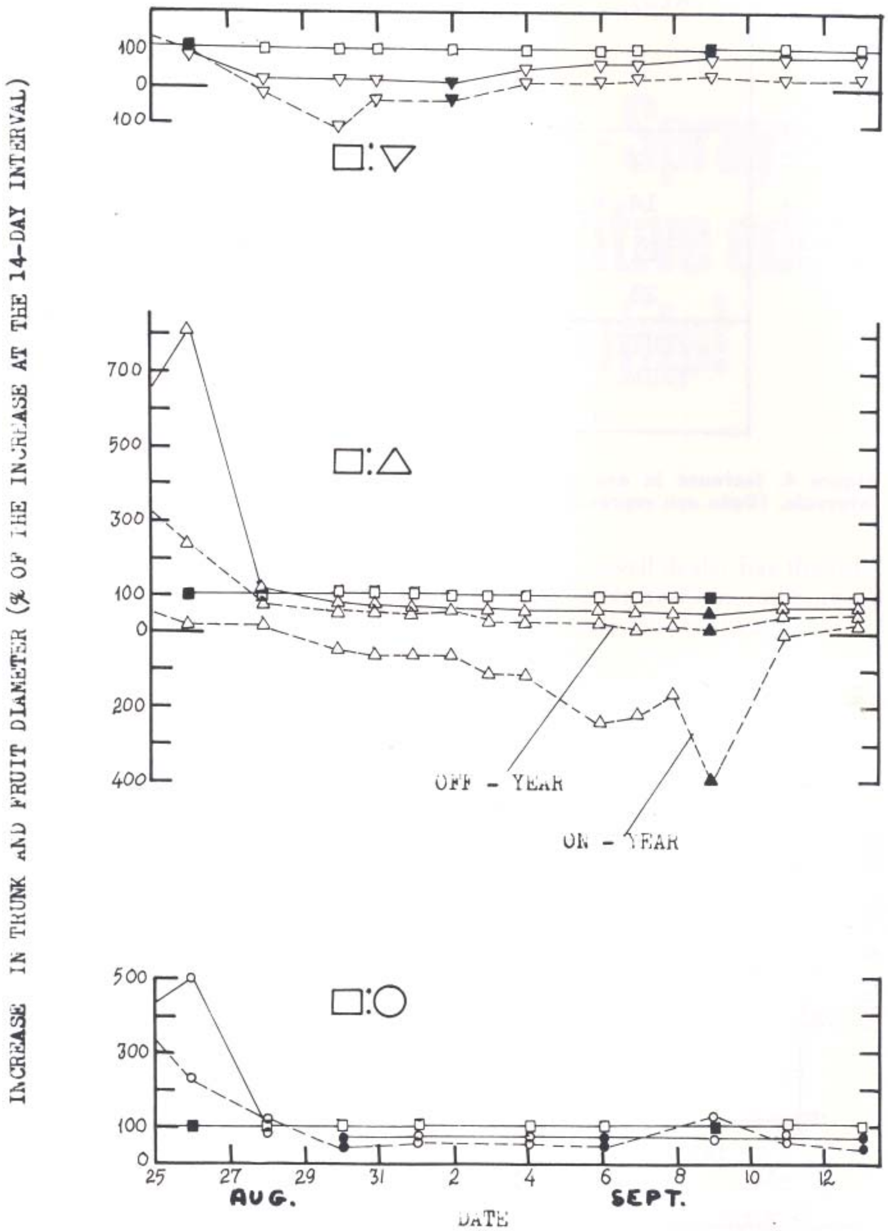
IRRIGATION INTERVAL (DAYS)	MEASUREMENT		OFF - YEAR		ON - YEAR	
	ON IRRIGATION DAY	ON OTHER DAYS	NO. OF FRUITS MEASURED	AVERAGE YIELD (KG/TREE)	NO. OF FRUITS MEASURED	AVERAGE YIELD (KG/TREE)
7	●	○	10	35	10	155
14	■	□	10	21	15	157
21	▲	△	5	28	15	126
28	▼	▽	10	25	20	148

Figure 3. The effect of irrigation interval and fruit yield ('on-year', 'off-year') on changes in the avocado fruit diameter (cumulative).

TABLE 3. Effect of irrigation interval on beginning of changes in certain physiological parameters of avocado trunk and fruit (in days, Aug.-Sept. 1970).

Parameter	*On-Year*				*Off-Year*			
Irrigation interval	7	14	21	28	7	14	21	28
Trunk growth cessation	3	3	6	7	6	8	11	14
Daily trunk contraction > 0.2 mm	2	6	7	10	3	10	13	12
Effective trunk contraction*	4	4	8	11	—	13	14	17
Fruit growth cessation	5	12	14	18	—	—	19	24

* *The number of days after irrigation when its effect on the decrease in trunk contraction ceases.*


INCREASE IN TRUNK AND FRUIT DIAMETER (% OF THE INCREASE AT THE 14-DAY INTERVAL)
□:▽
□:△
□:○
OFF - YEAR
ON - YEAR
25
27
29
31
2
4
6
8
10
12
AUG.
SEPT.
DATE

IRRIGATION INTERVAL (DAYS)	MEASUREMENT	
	ON IRRIGATION DAY	ON OTHER DAYS
7	●	○
14	■	□
21	▲	△
28	▼	▽
FRUIT	————	
TRUNK	— — — — —	

Figure 4. Increase in avocado trunk and fruit diameter at various irrigation intervals. (Data are expressed in percent of the increase at the 14-day interval).

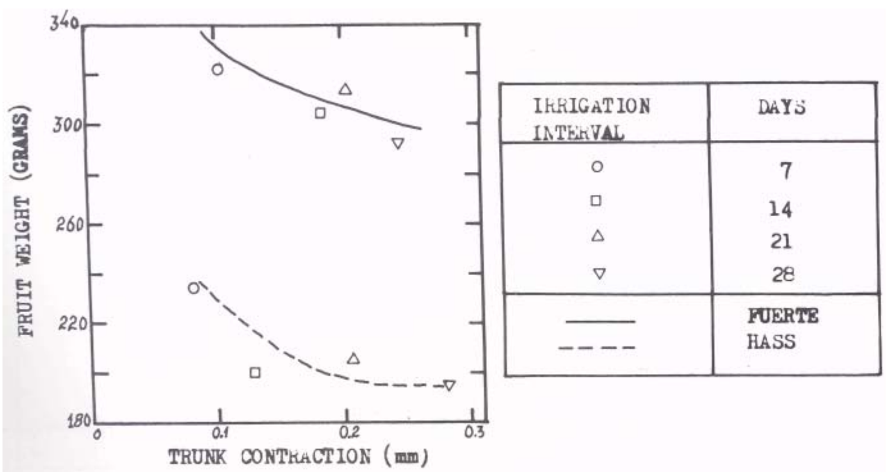


Figure 5. Interaction between average avocado tree trunk contraction on the day prior to irrigation, and the ripe fruit weight (1970). Each point represents an average of 15 trees.