

Aspects of the water economy of Hass avocado trees (*Persea americana*, cv. Hass). I. plant water status and gas exchange.

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ABSTRACT

Aspects of the water regime of Hass avocado trees were studied in a one hectare experimental plot in which the performance of a fully automated irrigation system based on water application in response to the diurnal cycling of leaf thickness was compared with three variations of conventional irrigation regimes. Gas exchange was studied in four series of measurements over a solar day with a Li-Cor 6200 infra-red gas exchange module. Simultaneous variations in leaf water potential (ψ_l), leaf thickness (IT), trunk radius (TR), soil water potential (SWP) and vapor density deficit were recorded.

Transpiration flux balanced recommended irrigation application rates. However, despite high rates of transpiration, stomates remained open enabling photosynthesis to continue unabated throughout the day. SWP at thirty cm. depth did not fall below -40 kPa. Leaf water potential varied in unison with LT and TR contractions, but never was more negative than -1.05 MPa at midday. Trunk contractions showed a 1-2 hr. lag in reaction time in respect to ψ_l , VDG and LT.

It was concluded from these results that there are significant differences in the water economy of the avocado tree as compared with other perennial orchard crops which have been studied more intensely, such as citrus.

INTRODUCTION

The avocado evolved as an understory species in the mountain rain forests of tropical America. This venue creates very specific anatomic and metabolic adaptations in whole plant and in particular in leaf tissue (Tanner & Kapos, 1982; Dhayani, 1989; Cavalier & Goldstein, 1989; Tyree & Ewers, 1991; Thompson *et al.*, 1992a, 1992b). When such a species is cultivated in different terrains, a degree of adjustment to the new environment ensues, which is, however, never complete in the course of a single, or even several, generations (Thompson *et al.*, 1992a, 1992b). The limited adaptations possible to developing leaves are usually irreversible. Thus, a leaf which flushed in full sunlight, but later is shaded by subsequent growth, will not revert to a shaded configuration after it has reached maturity. The source of the Hass variety is the mountainous rain forests of the islands of the West Indies. The cultivar is more prurient and slightly more tolerant of

salt stress than mainland varieties, but is consequently more sensitive to extremes in temperature and humidity (Bergh, 1985). These considerations are particularly pertinent to avocado culture in Israel and other areas in the world where avocados are grown under semi-arid conditions, such as Australia, South Africa, and Southwestern U.S. Avocados, in particular, have not developed any of the xeromorphic qualities that citrus (another tropical understory species) have acquired (Kreideman & Barrs, 1972).

The water regime of the avocado in relation to its adopted venues has been only sparingly investigated (Sterne *et al.*, 1977; Bower *et al.*, 1977; Kimmelman, 1979; Scholefield *et al.*, 1981; Ramadasan, 1981). In particular, the effects of water application on key metabolic processes such as stomatal efficiency (Scholefield *et al.*, 1981), dry matter accumulation (Kimmelman, 1979), or photosynthate allocation (Adato & Levinson, 1987) has been the subject of only widely isolated studies. It is the purpose of this study to examine correlations between water application on the one hand and environmental and plant parameters describing the water continuum between soil, plant and atmosphere, on the other.

MATERIALS AND METHODS

Avocado trees were studied in a 1.0 hectare experimental plot containing Hass, Fuerte and Ettinger cultivars planted in alternate rows. The plot was divided into sixteen random blocks of 15 trees, each block comprising one of four replicates of each of four irrigation treatments. The treatments compared irrigation with mini-sprinklers at 100% and 75% of recommended coefficients for Class "A" pan evaporation, drip irrigation at 100% of recommended application and an automated drip irrigation treatment triggered by a leaf thickness sensor developed by the authors. Trees of the Hass cultivar, the central trees in each block, were selected for study. In a central tree in one replicate of each of the irrigation treatments, trunk radius and leaf thickness were continuously and automatically monitored. Each station also included tensiometers at 30, 60 and 90 cm. depth, and instruments measuring air temperature, relative humidity and soil temperature at 10 cm. depth.

Table 1: The Irrigation Treatments

Treatment T-1:	Daily dripper irrigation at 100% of recommended rate.
Treatment T-2:	Daily pulsed dripper irrigation according to leaf sensor.
Treatment M-1:	Irrigation with mini-sprinklers every two days at 100% of recommended rate.
Treatment M-2:	Irrigation with mini-sprinklers every two days at 75% of recommended rate.

Dripper treatments were irrigated with two parallel lines of integral, volume regulated drippers, 3.6 l/hr ("Netafim", Israel) spaced one metre apart; hourly application rate per tree: 42 l/hr. Mini-sprinkler treatments were irrigated with a single volume regulated mini-sprinkler per tree, either 1 05 l/hr (Treatment M-1), or 78 l/hr (Treatment M-2).

On 21 Sept., 1995, four rounds of measurements of gas exchange were carried out with a Li-Cor 6200 infrared gas analyzer. Concurrently, leaf water potential was determined with a pressure bomb (ARI, Kfar Charuv, Israel). Four "sun" leaves on the station tree of each treatment were marked for mechanical leaf thickness readings and gas exchange measurements. Each leaf gas exchange measurement comprised 3 x 30 second

integrations. Vapor density gradient was calculated from Li-Cor leaf to air temperature differential data, and independent readings of ambient air temperature and relative humidity, assuming that leaf to air temperature differential as measured by the Li-Cor was the same as in exposed leaves. Boundary layer resistance to gaseous flow was estimated at 0.2 m/sec for calculation of transpiration rates. Resistance to CO₂ assimilation not attributable to stomatal influences, R_m, was calculated from the relationship of intercellular CO₂ concentration and net photosynthesis. At the conclusion of each round of gas exchange measurements, four leaves similar to those selected for gas exchange study were detached from each station tree for water potential determination.

Table 2. Results of 4 rounds of measurements taken on 21/9/95

Trt	Hr.	Rs	Rm	Tr	A	RLT	SWP	Δtk	Ψ _l
T-1	7:56	1.4	3.2	4.08	13.2	0.99	5.0	-1	-0.15
	10:39	2.9	4.3	8.05	7.96	0.95	8.0	15	-0.42
	11:53	4.7	9.9	5.29	4.34	0.93	8.0	26	-0.57
	14:29	15.0	25.0	1.49	1.44	0.87	11.0	48	-0.82
	AVG	6.1	10.3	4.73	6.75	0.94	8.0	22	-0.49
T-2	8:13	1.1	2.8	6.97	13.6	0.99	9.7	-0.5	-0.46
	10:48	3.0	4.2	7.97	9.42	0.98	6.5	4	-0.56
	12:02	5.1	10.1	5.06	4.18	0.96	6.5	5	-0.61
	15:00	4.7	11.3	4.62	3.25	0.93	8.0	8	-0.73
	AVG	3.5	8.6	6.16	7.61	0.97	7.6	4.1	-0.59
M-2	8:21	1.4	3.0	5.14	14.8	0.97	33.0	-1.5	-0.21
	10:57	4.0	5.9	6.15	5.99	0.91	36.0	8.5	-0.47
	12:16	5.6	23.9	4.61	1.80	0.91	37.0	10	-0.51
	15:08	4.4	8.6	4.64	4.01	0.90	38.0	13	-0.69
	AVG	3.8	10.3	5.14	6.66	0.92	36.0	7.5	-0.47
M-1	8:31	3.0	4.0	2.99	9.80	0.96	13.0	0	-0.34
	11:05	2.1	3.7	9.92	9.07	0.94	17.0	8	-0.63
	12:29	17.2	00	1.39	-0.6	0.89	23.0	13	-0.81
	15:17	3.1	3.4	5.91	8.13	0.88	25.0	17	-1.05
	AVG	6.3	?	5.05	6.57	0.92	19.5	9.5	-0.71

Rs = stomatal resistance (sec/cm); Rm = mesophyll resistance (sec/cm); Tr = transpiration (μg/cm²/sec);

A = net photosynthesis (μmol/m²/sec); RLT = relative leaf thickness; SWP = soil water potential (-Kpa);

Δtk = accumulated trunk contraction (μ); Ψ_l = leaf water potential (Mpa).

1. Data in columns 3-6 (Rs to A) represent average of four readings of 3x30 second integrations.

2. RLT and Ψ_l data are average of four determinations. Δtk are instantaneous readings taken during each round.

RESULTS AND DISCUSSION

Table 2 demonstrates that there were small (statistically non-significant) differences between the treatments. Photosynthesis (Pn) and transpiration (Tr) were slightly higher in the sensor treatment. However, annual water application over two growing seasons for this treatment, was only 78% of recommended rates (treatments T-1 and M-1), while

yield was slightly higher in the sensor treatment (data not shown). Notwithstanding transpiration rates (column TR, Table 2) that would cause partial wilting in citrus (Bravdo & Sharon, 1995), the most negative leaf water potential measured in any treatment was -1.05 MPa (see column ψ_l , Table 2). This conservatism in avocado leaf water potential has been discerned in the past (Sterne *et al.*, 1977; Ramadasan, 1981; Scholefield *et al.*, 1981), and would appear to be the result of a strategy calculated to prevent dessication of fruits, which store photosynthate as lipids, and therefore don't develop highly negative osmotic potentials as do fruits which store sugars. A corollary of this phenomenon was that stomates remained open and photosynthesis and transpiration continued unabated throughout daylight hours (columns 3-6, Table 2), on a dry (relative humidity minimum: 32%), and hot (air temperature maximum: 36°C.) day. A comparison of columns 3 & 4 (R_s , R_m), Table 2, and Figure 1 demonstrate that photosynthesis was controlled by mesophyll resistance, which in every instance was greater than stomatal resistance. Photosynthesis was well correlated, in a hyperbolic relationship, with both stomatal and mesophyll resistance (Fig 1). Leaf water potential in general reflected losses in leaf thickness and trunk radius (Table 2). However, turgor potential, as calculated from relative leaf thickness (Sharon & Bravdo, 1996) was slightly better correlated to net photosynthesis ($R^2 = 0.46$) than leaf water potential ($R^2 = 0.381$).

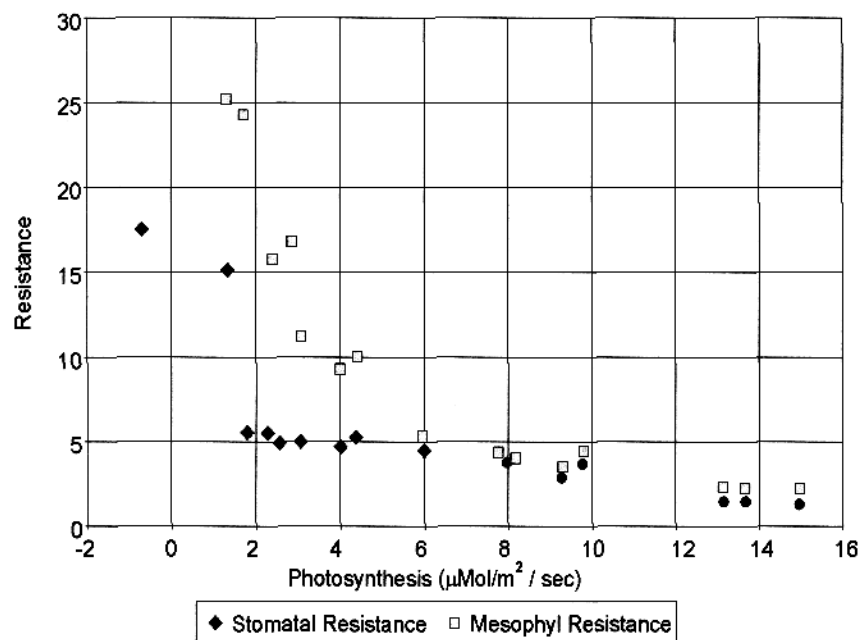


Figure 1: Resistances vs Photosynthesis - Avocado 9/21/95

Figure 2 shows that trunk contraction began 1 hour later than leaf thickness contraction and remained at minimum levels until 1700 hours, while leaf thickness began to recover between 1300 and 1400 hours. Soil water potential showed even greater lag time and rarely recovered until pre-dawn the following day (data not shown). Trunk contractions reflected the irrigation regime and soil water potential, as shown by higher minimum values for trunk contraction on alternate days when water was applied (see Fig 2), while

leaf thickness closely followed the variations in transpiration demand (vapor density gradient, $R^2 = 0.93$).

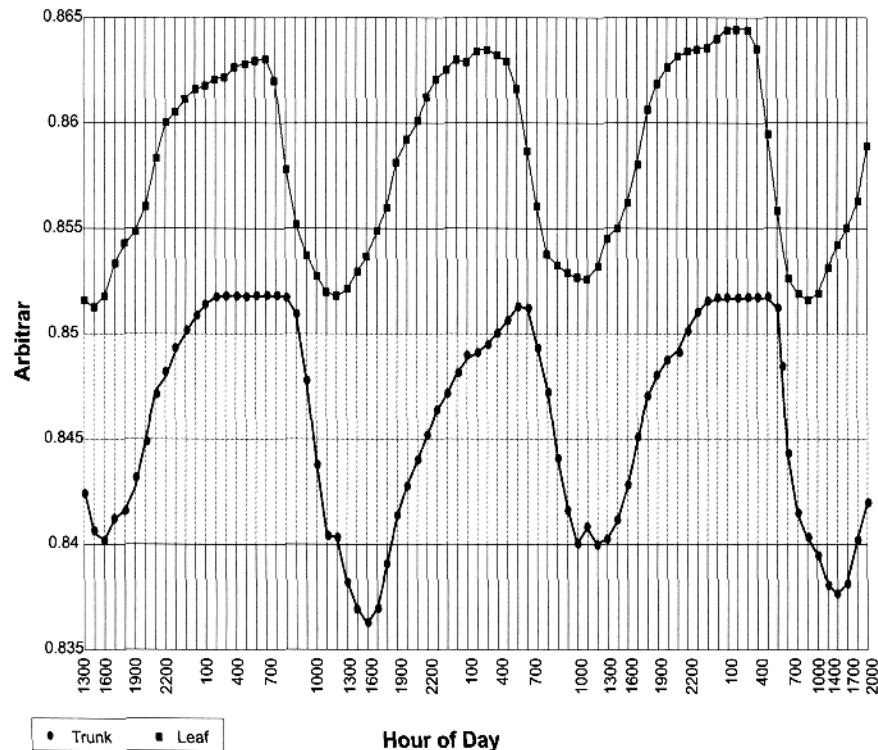


Figure 2: Avocado Leaf and Trunk Sensors 21-24/9/95

The ability of avocado trees to maintain leaf metabolism in the face of transpiration rates which would cause partial wilting in citrus is an anomaly not explained by the data in this report and warrants further study.

REFERENCES.

- ADATO, Y. & LEVINSON, B. 1988. Influence of daily intermittent drip irrigation on avocado (cv. Fuerte) fruit yield and trunk growth. *J. of Hort. Sci.* 63(4):675-685.
- BERGH, B.O. 1986. *Persea Americana*, in CRC Handbook of Flowering, Halevy, A.H. (ed.) CRC Press, Boca Raton, FL.
- BOWER, J.P., WOLSTENHOLME, B.N. & DE JAGER, J.M. 1977. Incoming solar radiation and internal water status as stress factors in avocado, *Persea americana* (Mill.) cv. Edranol. Proceedings of Technical Committee, South African Avocado Growers' Association, pp. 35-40.
- CAVELIER, J. & GOLDSTEIN, G. 1989. Elfin cloud forest tree species, In: Structural and functional responses to environmental stresses, Kreebe, K.H., Richter, H. & Hinckley, T.M. (eds.), The Hague. pp. 243-253.
- DHAYANI, R. R. 1989. Responses of sun and shade grown tree leaves to water vapor transfer processes and energy exchange characteristics, *Op. cit.* pp. 191-198.

- KIMMELMAN, R. 1979. The influence of different temperatures and light intensities on gas exchange of avocado leaves (*Persea americana* (Mill.)). M. Sc. Agric, thesis, Hebrew University of Jerusalem, Rehovot, Israel.
- KREIDEMANN, P.E. & BARRS, H.D. 1981. Citrus Orchards, In: Water Deficits and Plant Growth. Kozlowski, T.T. (ed.), v. 6, ch. 5.
- NAOR, A. 1997. Developing parameters for regulating avocado irrigation. Conference on Regulation of Orchard Irrigation, Bet Dagan, Israel (in Hebrew).
- RAMADASAN, A. 1981. Gas exchange in the avocado leaves under water stress and recovery. *California Avocado Society Yearbook.*, pp.147-151.
- SCHOLEFIELD, R.B., WALCOTT, J.J., KREIDEMANN, P.E. & RAMADASAN, A., 1981. Some environmental effects on photosynthesis and water relations of avocado leaves. *Op. cit.* pp.93-103.
- SHAKEL, K.A., AHMADI, H., BIASI, W., BUCHNER, R., GOLDHAMER, D., GURUSINGHE, S., HASEY, J., KESTER, D., KRUEGER, B., LAMPINEN, B., MCGOURTY, G., MICKE, W., MITCHAM, E., OLSON, B., PELLETRAU, A., PHILIPS, H., RAMOS, D., SCHWANKEL, L., SIBBETT, S., SNYDER, R., SOUTHWICK, S., STEVENSON, M., THORPE, M., WEINBAUM, S., YAEGER, J. 1997. Plant water status as an index of irrigation need in deciduous fruit trees. *HortTechnology* 7(1):23-29.
- SHARON, Y. & BRAVDO, B. 1996. Irrigation control of citrus according to diurnal cycling of leaf thickness. 7th Annual Conference on Water and Irrigation, Tel Aviv, Israel. pp.273-283.
- STERNE, R.E., KAUFMANN, M.R. & ZENTMEYER, G.A. 1977. Environmental effects on transpiration and leaf water potential in avocado. *Physiol. Plant.* 41:1-6.
- THOMPSON, W.A., KREIDEMANN, P.E. & CRAIG, I.E. 1992a. Photosynthetic response to light and nutrients in sun-tolerant and shade-tolerant rainforest trees. I. Growth, leaf anatomy and nutrient content. *Australian J. Plant Physiol.* 19:1-18.
- THOMPSON, WA, KREIDEMANN, P.E. & CRAIG, I.E. 1992b. Photosynthetic response to light and nutrients in sun-tolerant and shade tolerant rainforest trees. II. Leaf gas exchange and component processes of photosynthesis. *Australian J. Plant Physiol.* 19:19-42.
- TYREE, M.E. & EWRERS, F.W. 1991. The hydraulic architecture of trees and other woody plants. *New Phyt.* 119:345-360.