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IMPROVING AVOCADO TREE WATER STATUS UNDER SEVERE CLIMATIC CONDITIONS BY INCREASING WETTED SOIL VOLUME

T. Cantuarias
Y. Cohen
Institute of Soils and Water
ARO, Bet-Dagan POB 6
50250, Israel.

E. Tomer
Institute of Horticulture ARO,
Bet-Dagan POB 6
50250, Israel.

Abstract

An irrigation experiment was conducted in an adult avocado orchard in order to study the effect of enlargement of the wetted soil volume on tree water status under conditions of high evaporative demand, like those registered in Israel in the early spring during the avocado flowering and fruit set stages. Enlargement of the wetted soil volume from 25% to 75% increased root growth rate and improved tree water status and transpiration response to high evaporative demands.

1. Introduction

Among the main factors that have been described as detrimentally affecting avocado yield in Israel, the influence of adverse climatic conditions on canopy water status during the flowering and fruit set stages is of great importance (Levinson and Adato, 1991; Lomas, 1992; Lomas and Zamet, 1994). Periods of high air temperature accompanied by low relative humidity cause a massive abscission of flowers fruit and leaves, thus reducing the potential yield of avocado trees (Tomer, 1977; Argaman, 1983). Under these extreme climatic conditions even the water supplied by irrigation is not enough to avoid canopy water stress and fruit drop (Honing and Lavee, 1989). This fact has been attributed to a limited size of the tree's root system at the early spring season, which reduces the absorptive surface able to uptake water from the soil (Gefen, 1981).

This limited water uptake capacity may be improved by enlargement of the soil volume occupied by the roots that will moderate canopy water stress developing under severe climatic conditions. This hypothesis was tested in the present study by applying two different wetted soil volumes to modify root system distribution.

2. Material and methods

The experiment was conducted during two years (1993-1994) in a 14-year-old avocado orchard cv. Ettinger planted at 6x6 m spacing, in the Gilat Experimental Station in the northern Negev (31º20’ N; 34º40’ E), at 150 m above sea level. The soil of the experimental field is a loessial sandy loam, with a uniform soil profile to a depth of 180 cm (Steinhardt and Tomer, 1988). Two irrigation treatments with different wetted soil volumes were applied, each one on four experimental plots: (i) irrigation by one drip lateral line along the row line, wetting 25% of the soil surface, and (ii) irrigation by five drip lateral lines, distributed in parallel to the row line, wetting 75% of the soil surface. Both treatments received the same amount of water on a weekly basis, but with a different frequency: irrigation was given twice a week for the 1-drip line treatment, and once a week for the 5-drip lines treatment.

Tree transpiration rate (T) was determined from sap flow measurements by means of a calibrated heat-pulse technique, as described by Cohen et al. (1981) and Cohen (1991).

Root distribution was examined at trenches (100 cm depth, 300 cm length, 50 cm width) dug perpendicular to the row line on two trees per treatment. Water pots were placed in the bottom of the trenches to maintain high relative humidity, and the trenches were covered with a thick double black- plastic sheet. Roots were monthly counted on both walls of the trench using a 18 cm grid. After counting, root tips were removed from the wall surface.

Soil water content was measured with the neutron scattering method on two trees per treatment. Eight aluminum access tubes were placed perpendicular to the trunk, and five soil depths were monitored (25, 55, 85, 115 and 145 cm).

Leaf xylem water potential (LWP) was measured during the morning on shaded and sunlit leaves on two trees per treatment, using a pressure chamber (Arimad 2, Kibbutz Kfar Charuv, Israel). Sunlit canopy temperature (T_c) was measured during the morning with a hand-held infrared thermometer on four trees per treatment (Model 43S, focal plane 8 cm., Telatemp Corp., Fullerton CA, USA).

Weather measurements were recorded at 2 m height from an automated meteorological station located 300 m outside the orchard. These data were used to compute the potential transpiration (T_P) according to a modified Penman-Monteith equation (Fuchs et al., 1987).

3. Results

Soil water distribution was more extensive in the treatment irrigated by 5-drip lines. In this treatment the end of the wetting front was located at 225 cm from both sides of the row line, as compared to 110 cm for the treatment irrigated by 1-drip line. In both treatments water was mainly extracted from the first 55 cm of the soil profile. Figure 1 shows the average rate of root tips appearance measured at different distances from the row line on both treatments during May-June 1994, when root activity was at its maximum. In both treatments, a gradual reduction of root appearance with increasing distance from the row line was observed. The 1-drip line treatment developed more roots in the first 50 cm from the row line. However, at larger distances from the row line, the treatment irrigated by 5- drip lines showed higher rates of root appearance. Average rate of root appearance during the period was higher for the 5-drip lines treatment, 8.1 root tips m^2 day^{-1}, as compared to only 5.5 root tips m^2 day^{-1} in the 1-drip line treatment. Analysis of root distribution with depth form soil surface indicated that 69% and 80% of the total roots are concentrated in the first 36 cm of the soil for the 1-drip line and the 5-drip lines irrigation treatments respectively, confirming the characteristic shallow distribution of avocado roots (Levinson and Adato, 1991; Michelakis et al., 1993).

Figure 2 shows the course of T and T_P for both treatments measured during a 16-day period on May 1994. Transpiration values correspond to the average data of 4 trees per treatment. Arrows indicate the irrigation dates for the 5- drip lines treatment. This treatment showed higher average T rates during the whole period, as compared to the 1-drip line treatment. However, the considerable variability in transpiration found within trees of the same treatment does not allow to consider the average T values in absolute terms. As seen in the figure, T of the 5-drip lines treatment increased immediately after the irrigations, and decreased approximately four days afterwards. Such variations of T with time after the irrigation may be explained by a larger water uptake from the soil that allows the increment of T after the irrigation, and by a reduced soil water availability towards the end of the irrigation interval. However, these variations of T_p are also a consequence of an increase in T_p observed after the irrigations, and a coinciding decrease of T_p occurring approximately four days after the irrigation. These results indicate that avocado transpiration is influenced both by soil water availability and by climatic conditions.

Therefore, in order to isolate the effect of soil water availability on the transpiration response to climate, we analyzed data collected during a period when both treatments were daily irrigated, hence soil water availability was not limited. Figure 3 presents the variation of the avocado T/T_p ratio with increasing T_p values registered during an 11-day period in May 1994, when irrigation was daily applied to both treatments because of the occurrence of severe hot spells. The T/T_p ratio of both treatments increased with higher T_p, however a larger increment was observed in the treatment irrigated by 5-drip lines. Analysis of these data indicated that T increased by nearly 15% and 20% in the 1-drip line and 5-drip lines treatments respectively, following a change in T_p from 8.5 to 9.4 mm day^{-1} (11%). These results indicate that under non-limiting soil water availability, avocado T increases at a higher relative rate as compared to the increment in $T_.$

Figure 4 presents the simulated variation of the avocado T/Tp ratio with increasing air temperature and relative humidity. The T/T_p ratio was computed from the modified Penman-Monteith equation utilized in this study, considering climatic parameters and canopy structure data measured in the field as inputs of the model. Three levels of canopy water stress were considered in the simulation by introducing different canopy conductances (0.10, 0.08 and 0.05 cm s^{-1} for none, moderate and severe stress). The figure shows an increase of T/T_p ratio with increasing air temperature irrespective of ale water stress level, while no significant effect of increasing relative humidity on T/T_p, was observed.

Figure 5 presents the variation of LWP measured at noon on both treatments during April-May 1994. Under a given T rate, *LWP* of the trees irrigated by 5-drip lines was higher &an in the trees irrigated by 1-drip line, both on sunlit and shaded leaves. Although data were taken only from days when the soil was wet - to eliminate the effect of soil water availability on xylem potential- changes in *LWP* were poorly related to T_p - This poor relationship may be associated with the response shown in Figure 3, of a higher relative increment of T compared to the increment of T_p that maintains a favorable tissue water status.

Figure 6 shows the canopy temperature difference between the treatment irrigated by 1-drip line and the treatment irrigated by 5 lines $(Tc_1\text{-}Tc_5)$, as measured at three time periods during the morning, on April-May 1994. $Tc_1\text{-}Tc_5$ reached its maximum value of 1.5-2.0 ºC between 8:30-9:30 h, indicating the development of a more severe canopy water stress in the 1-drip line treatment. Towards the noon, $Tc_1\text{-}Tc_5$ decreases, and even positive differences were observed, probably as a consequence of an increased stomatal resistance affecting both treatments during these hours.

4. Discussion

Enlargement of wetted soil volume and root growth of an avocado orchard improves water uptake and allows an increased T rate under conditions of high evaporative demand, thus preventing canopy water stress. Under non-limiting soil water availability, avocado tree transpiration increases in a higher relative rate as compared to the increment of T_p. This situation can only occur if stomata remain open and no restrictions to available soil water are imposed. Under high atmospheric demands, the increment in air temperature will raise leaf temperature over that of the air. Higher leaf temperature will then increase the saturated water vapor pressure in the substomatal chambers of the leaf, thus promoting the evaporation rate and water loss from the canopy, and explaining the increment of the T/T_p ratio observed under these conditions.

The improved water uptake and favorable canopy water status achieved by enlarging the wetted soil volume were expressed as higher LWP and lower T_c during periods of high evaporative demands.

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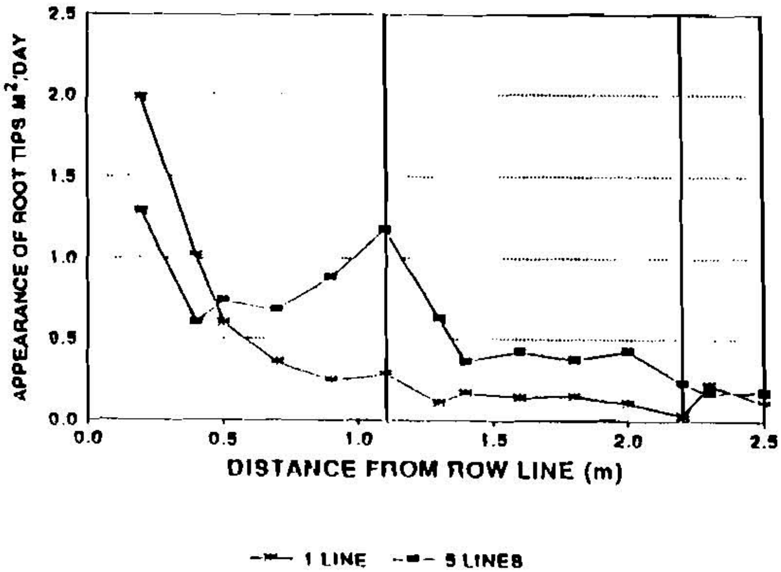

Figure 1. Variation of the annual average rate of root tips appearance with distance from the row line, as observed on both treatments during the second irrigation season (1994).

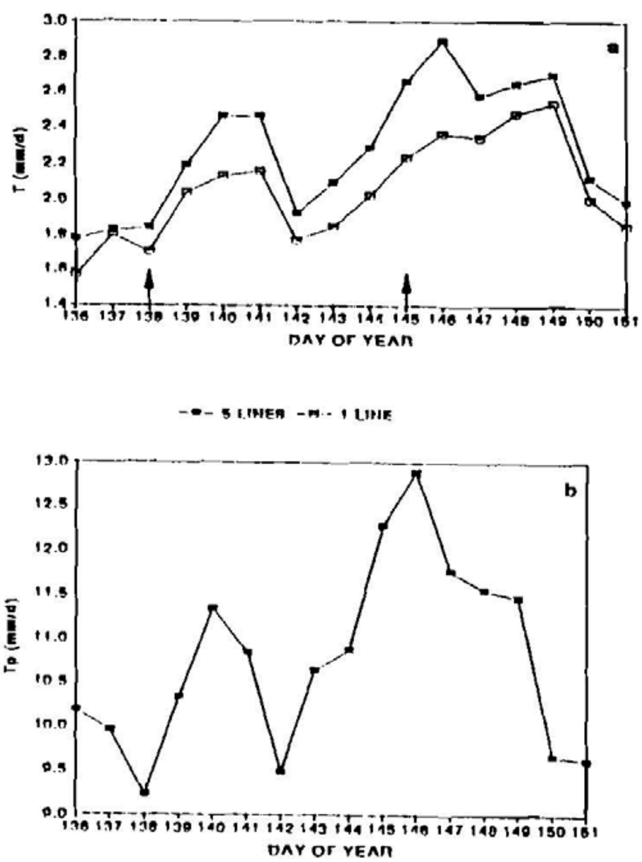

Figure 2. Course of: (a) daily average transpiration (*T*) of the irrigation treatments, and (b) potential transpiration (*Tp*) during a period of sixteen days in May 1994. Arrows indicate the irrigation dates of the 5-drip lines treatment.

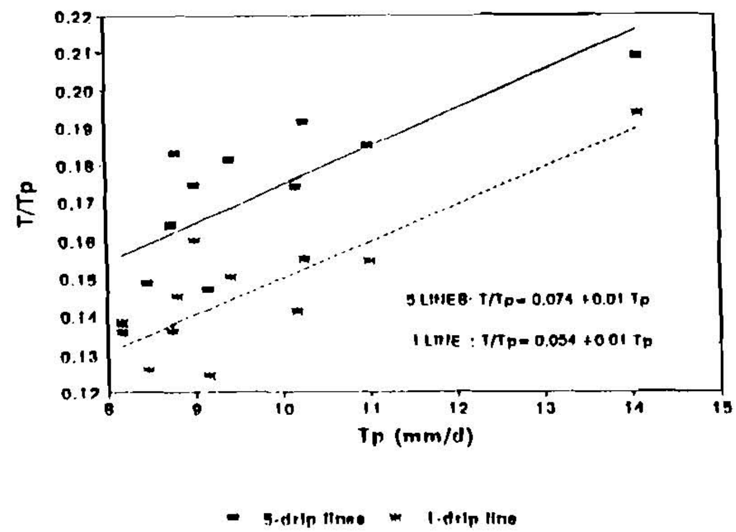

Figure 3. Relationship between the *T/Tp* ratio and potential transpiration (*Tp*) observed on both treatments in May 1994, under non-limiting soil water availability.

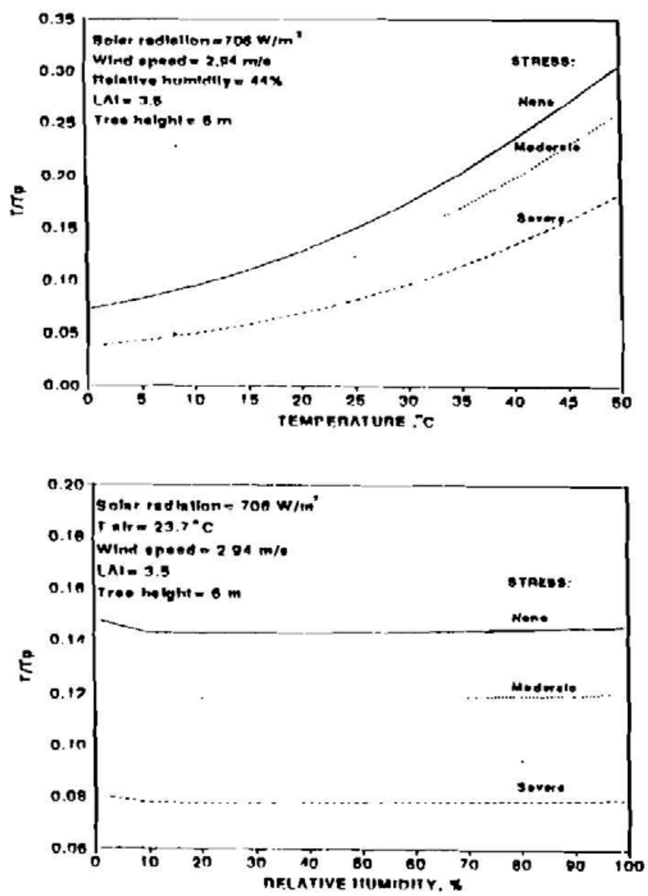

Figure 4. Simulated variation of avocado's *T/Tp* ratio with: (a) air temperature, and (b) relative air humidity under three canopy stress levels, according to a modified Penman-Monteith model.

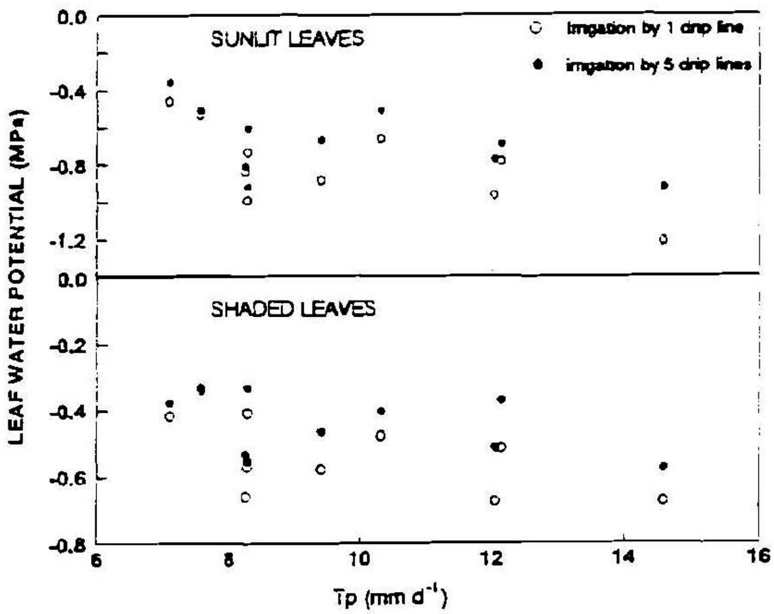

Figure 5. Variation of noon xylem leaf water potential (LWP) with increasing *Tp* measured on both irrigation treatments during April-May 1994, on sunlit and shaded avocado leaves.

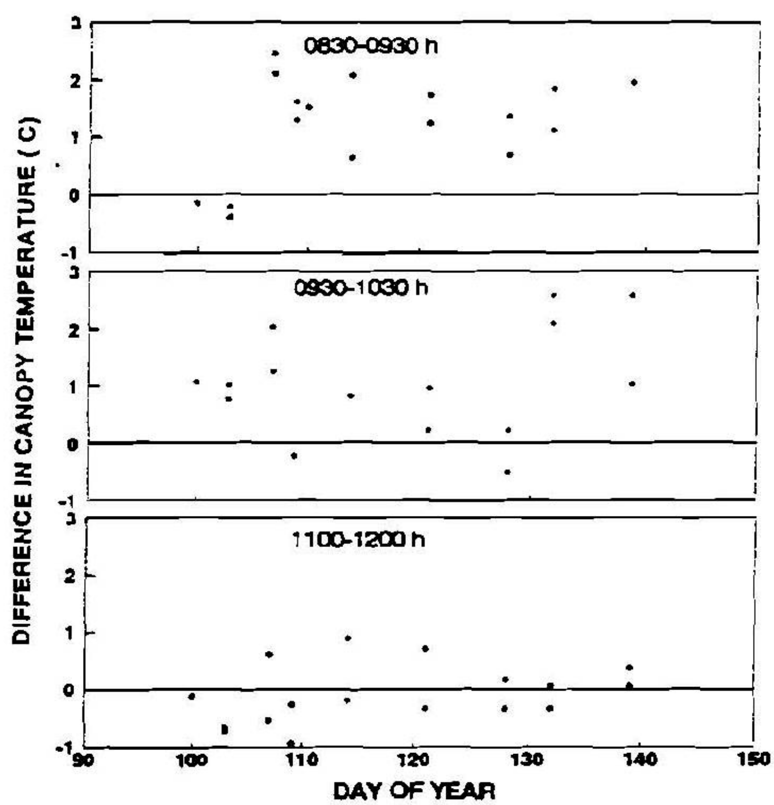

Figure 6. Course of the temperature difference between the 1-drip line and the 5-drip lines irrigation treatment, measured with a hand-held infrared thermometer at three time intervals in the morning during April-May 1994.