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The Response of Avocado Trees in the South of Spain to Different Irrigation Regimes and Wetted Areas

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***Abstract.* A four-year field trial was carried out in a commercial avocado orchard in Vélez-Málaga (Málaga, Spain) using 48 five-year old avocado trees cv. Hass. Planting distance was 5x4 m, the total area covered at the beginning was 55%. The stony soil (45% > 2mm) had a low water retention capacity (16%). The experimental design employed four replicates.**

Water applications were controlled by automatic valves and meters. Irrigation was daily during the summer for the 4 drip treatments and every 2 and 3 days, respectively, for T5 and T6 microdiffuser treatments. Soil humidity was monitored with tensiometers arranged in a 3x3 vertical lattice below and to one side of each emitter in each elemental plot. Tree growth was evaluated yearly by calculating trunk cross-sectional area. The fraction of covered soil was measured twice yearly. Yield per tree and evaporation from wet soil were also measured.

Soil water potential (SWP) immediately before irrigation depended on water supply and wetted area. It was higher with more water (T3 vs T2 and T1) and with more wetted area in drip irrigations (T4 vs T2). It was also higher with drip irrigation (T2 than with microdiffusers treatments (T5 and T6). Vegetative growth correlated directly with the SWP but there were no significant differences between yields. Only the T6 treatment showed a lower yield that was associated with smaller growth and larger numbers of tensiometer readings above the 3 cm Hg critical value. Some applications of these findings to the irrigation needs of the avocado tree are discussed.

The avocado *(Persea americana)* crop has became a very important part of the agricultural economy on the fringe of the southern Mediterranean coast of Spain but particularly in the provinces of Málaga and Granada. The total area devoted to cultivation of avocados is 4,800 ha (Farré, 1987). The first cultivations and experimental trials during the 1970's showed that avocado trees were very dependent on a regular and continuous supply of water (Farré, 1979). This field trial was undertaken because there are now difficulties with the water supplies in this area. It aimed to establish more precise data about avocado tree water requirements and the influence of mild hydric stress on tree growth and production and to compare several different irrigation techniques (microdiffusers (MD)-relatively high wetted areas- and traditional drippers (DR)).

Materials and Methods

The trial was carried out in the Vélez-Málaga area in a five-year-old commercial orchard. The avocado trees, cv. Hass, were grafted onto rootstocks grown from seeds of cv. Bacon. The trees were cultivated in a leveled terrace from which the original 5 cm superficial soil layer had been removed and replaced after leveling. The total area planted was 1.6 ha and the spacing was 5x4 m.

The soil is stony, formed by the weathering of slate rocks, (46% > 2mm) with a fine sandy-loam fraction that is low in calcium carbonate and has moderate fertility. Some differences were detected between blocks (density and fraction between 2 and 1 mm (Olalla, 1988). Field capacity was low (14-16%) and the useful water (soil humidity tension < 40 cm Hg) was 6 to 8%.

There were 6 treatments and 4 blocks with 2 trees in each elemental plot. We chose a three-year experimental period and the optimized design was based on the work of Schaffer and Baranowsky (1986). The treatment protocol are presented in Table 1. The crop coefficient (K^,)

values could be changed during the experiment because we wanted the T2 treatment to simulate a commercial cultivation with soil humidity tensions (SHT) values that ranged between 0 and 30 cm Hg. The other treatments were adjusted proportionately.

The volumetric valves controlled the water application automatically. The flow meters were read every 1 5 days. Twenty-four sets of mercury tensiometers were installed with each one having 9 measurement points. The tensiometers were arranged in a 3x3 vertical lattice below and to one side of the emitter and extended to the margin of the wet bulb. Depth intervals were 25 cm and the horizontal intervals were 18 cm for the DP system and 5 cm for the MD system.

From January to March, 1987, both the old and new irrigation systems were operated together. After April the different treatment applications were started. Because of the low field capacity and hydraulic conductivity, daily applications were needed for the DP irrigation. The MD irrigations used the same frequency. The evaporation from a class A tank (EVo) was measured daily at 20:00 h. The field was irrigated during the night to take advantage of low-cost electricity and to reduce MD evaporation losses.

After the first experimental period (1987), it became clear that the application of a "normal" amount of water in combination with a high wetted area produced high soil humidity tensions (SHT) because of the large evaporative losses from the wet soil surface. To reduce this waste of water, we adjusted the MD irrigation frequency according to the soil characteristics determined in the preparative study to obtain water penetration to 6 cm. In this way the average irrigation frequencies in summer were 2 days for the T5 treatment and 3 days for the T6 treatment.

Until March, 1990, we recorded data about trunk cross-sectional area at 3 cm above the ground and yield. SHT's were monitored before the irrigations (between 19.0 and 20.0 h), 3 times/week during the summer and 1 or 2 times/week during the other seasons. They were also monitored occasionally after irrigation and during the following day to assess water movement in soil and possible percolation losses. Evaluations of evaporative losses from the wet soil were made by using 13x10 cm containers buried in the soil each refilled with a soil core sample.

Results and Discussion

The experiment yielded a large amount of data but only the most important are reflected in Table 2.

Water application. Water applications were roughly regulated according to the previous K,, to give the values forecast except for the T5 and T6 treatments. KC values of similar magnitude (0.5 or below) were proposed by Peck (1985) for controlled irrigations with no percolation losses.

Wetted Area. The differences between the wetted areas of the T1 to T3 treatments all using the same number of drippers were caused by the different amounts of water applied in each irrigation. There is not much information in the literature about this matter, but Gustafson *et al.* (1979) suggests wetted areas very similar to those in this present work. He also expressed the opinion that larger wetted areas might give better plant development. The response of yield suggests that the wetted areas in the T1 and T2 treatments were sub-optimal.

Growth and Yield. The differences were small and correlated directly with the amounts of applied water. Increasing wetted areas without increasing the amount of water did not significantly increase yield. In fact there was a significant decrease in the T6 treatment that we will discuss later. Results of other studies in Israel (Tomer, 1988) and California (Gustafson *et al.,* 1979) confirm that microjet irrigations need more water to give similar results to those of drip irrigations.

Soil Humidity Tensions (SHT). Because visual inspections have shown that the root system never penetrates below 6 cm, we arbitrarily separated the averages for the root (25-50 cm) and subsoil zone (75 cm). Larger amounts of water correlated with lower SHT and it is interesting that the T4 treatment gave similar SHT to those of the T3 treatment with less water consumption because the larger WA apparently reduced percolation. The T5 and T6 treatments gave higher SHT values possibly because the intervals between irrigations were longer and the evaporation losses were higher. The T6 treatment gave the highest SHT in the subsoil zone.

We cannot quantify exactly the percolation losses but the data gives an indication of their magnitudes. Measurements of SHT made early in the morning (0800-1000 h) revealed that percolation losses (SHT<5 cm Hg) as suggested by Farré (1979) and the recorded EVo values were connected. This is not surprising if we bear in mind that the amount of water supplied was controlled according to the EVo. We have established the "critical" EVo values shown in Table 3. Moreover, we calculated the EVo excesses above the "critical" values, these were totaled and compared to the total EVo for the period from June to September (Table 3). These results suggest that the useful soil water was very similar to that of the DP treatments (T1-T4) and also that the observed differences in yield and growth may be due more to WA than to the amount of water applied.

Returning to the subject of SHT, we suspect that the average values may have masked the real circumstances of the soil-plant relationship. The SHT values recorded immediately to the side of an emitter were generally low and of course they really represent only a small cylindrical volume of soil. However, the measurements made at the margin of the DR wetted zone revealed large variations. Additionally, visual inspections revealed that the root systems in this area were poorly developed. The last line of Table 2 takes this into account showing the SHT averages only for the tensiometers at depths of 25 and 50 cm in the middle of the wetted zones. The value of 3 cm Hg was considered to be "critical" (Farré, 1979; Gustafson *et al.,* 1979) in our evaluation of plant stress.

These results suggest that hydric stress is more continuous in MD treatments. There were no differences in stress between the T1 to T3 treatments and there was an almost complete lack of stress in the T4 treatment (Table 2).

The yields correlated significantly with the different SHT values (Table 4).

Wet soil evaporation losses (WSEL). The results of the experiments carried out during the summer period were very variable (between 0 and 3 mm/day). The maximum WSEL were 4.5 mm in the intervals between irrigations (T6). The WSEL was calculated and expressed as a percentage of the amount applied. The drip treatments gave very low WSEL. For the MD treatments (T5 and T6), values ranged from 16 to 24%, respectively. These results suggest that for large wetted areas, evaporative losses would be considerable and they may explain in part the poor results of the MD treatments.

Conclusions

Our results were obtained with relatively young trees over a period of only three years. However, they appear to have value for future irrigation management in our area. The use of a K_c below 0.55 would reduce both yield and growth and perhaps over longer experimental periods these reductions might be larger. Whether K_c values above 0.55 would be better has yet to be proved. Using this K_c value, we could reasonably expect to obtain an average annual water consumption of about 8.50 m^3/ha.

More investigation will be required to determine whether more sophisticated and expensive irrigation systems would reduce the percolation losses under the parameters used in this study. We calculate a 14% value for the T2 treatment (Table 3).

The avocado tree is particularly sensitive to high values of SHT. The high values measured in this study were either the result of water applications below K_c =0.55 or were associated with high evaporative water losses.

The results also suggest that the microjet irrigation systems (high WA) would need more water to produce similar yields and growth.

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Table 1. Irrigation Treatments.

	Treatments					
	T1	T2	T3	T4	T5	T6
K_c	0.4	0.5	0.6	0.5	0.5	0.5
Emitters by tree [z]	3 drip	3 drip	3 drip	5 drip	1 micro	2 micro
% wetted area (25 cm)	10	13	16	25	43	54

[z] Drippers with 4 L/h flow, and microdiffusers with 20 L/h.

Table 2. Summary of Main Results.

	Treatments					
	T1	T2	T3	T4	T5	T6
Water applied (m^3/ha/yr)	6736	8798	10,243	7975	7945	8207
K_c-summer	0.44	0.57	0.66	0.57	0.50	0.46
Wetted area (%)	10	13	16	25	43	54
Yield (kg/tree/yr)	19.1	20.7	22.2	22.0	20.4	17.2
Trunk cross sectional area (cm^2/3yrs)	140	160	175	166	140	154
Soil tension humidity (cm Hg) avg. summer: Root level 25 to 50 cm	22	19	12	14	25	24
Root level 75 cm	15	10	7	11	14	23
% Frequency of SHT < 5 cm Hg after irrigation (deeper location)	39	63	84	53	44	24
% Frequency of SHT > 30 cm Hg	15	16	16	8	33	41

Table 3. Critical values of EVo (mm that cause percolation losses during irrigation and an estimation of water losses (%).

	Treatments					
	T1	T2	T3	T4	T5	T6
EVo critical (mm)	10	8	7	10	>15	>30
% Water percolation losses	5.4	14.2	22.8	5.4	0	0

Table 4. Correlation Coefficients Between Yields and Soil Humidity Tension.

	Soil Humidity Tension (cm Hg)			
	Root level	75 cm depth	Percolation (%)	Stress (%)
Average yield(| r | >0.70, P<0.05)	-0.80	-0.94	0.86	-0.73