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Water Use of Young Citrus as a Function of Irrigation Management and Ground Cover Condition

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Key words: Trickle irrigation; lysimeter; potential evapotranspiration; crop evapotranspiration; crop water use coefficients.

ABSTRAK

Kertas kerja ini menerangkan kesan perairan dan pengurusan penutup bumi ke atas sejat pepeluhan, tamanan (ET) pokok limau muda jenis Valencia di atas tanah pasir halus Arredondo. Enam perlakuan yang berlainan telah digunakan: tiga paras potensi air tanah dan dua paras keadaan penutup bumi. Keputusan yang diperolehi dalam perlakuan yang mempunyai rumput penutup memerlukan lebih 50% air daripada perlakuan tanpa rumput penutup. Sejat perpeluhan berkait secara positif dengan jumlah perairan yang diberikan. Angkali penggunaan air tanaman (Kc) lebih tinggi daripada perlakuan tanpa rumput penutup. Angkali penggunaan air tanaman menurun apabila upaya air tanah yang dikenakan menurun.

ABSTRACT

This paper describes the effect of irrigation and ground cover management on crop evapotranspiration (ET) of young Valencia citrus trees grown on Arredondo fine sand. Six different treatment combinations were used: three levels of soil water potential and two levels of ground cover condition. Results obtained with grass cover treatments required 50% more water than with no grass cover treatments. Evapotranspiration correlated positively with the amount of irrigation applied. Monthly crop water use coefficients with grass cover treatments were 50% higher than with no grass cover treatments. Crop water use coefficient decreased as soil water potential decreased.

INTRODUCTION

Water is important to crop in providing a soil environment for the development of root system, and supplying water for plant use. Soil moisture must be maintained in a range that permits absorptions of water by plant roots at a rate comparable to evapotranspiration losses.

Evapotranspiration rate is affected by many factors, the most important of which are the amount of leaf area, stage of crop growth, climate and soil. The most important climatic factor affecting evapotranspiration is solar radiation.

A study of efficient use of irrigation water and accurate prediction of crop water is an important step in reducing cost of production of the crop. Therefore, knowledge of crop water use is essential for efficient irrigation management.

The use of trickle irrigation has received considerable interest in the past few years because of its ability to minimize water use, increase water use efficiency (Harrison *et al.*, 1984) and efficiently substitute the conventional irrigation without adverse effects on crop performance (Bester *et al.*, 1974). Using trickle irrigation, water can be saved because non-productive water used by evaporation and weed growth between trees can be minimized, especially during the early stage of growth (Fereres *et al.*, 1982).

The objectives of this investigation were:

1. To determine water use by young citrus trees irrigated with trickle system under two different ground cover conditions.
2. To evaluate crop water use coefficients as a function of soil water potential and ground cover conditions.

MATERIALS AND METHODS

Description of Experimental Facilities

The experiment was conducted at the Irrigation Research and Education Park in Gainesville, Florida. Two year-old Valencia citrus trees (*Citrus sinensis* L.) grafted on sour orange root stock were transplanted in drainage-type lysimeters. The lysimeters were buried in the soil so that the soil inside and outside the lysimeters was at the same ground-level. The soil was Arredondo fine sand (Hyperthermic, uncoated Typic Quartzipsamments).

Automatic rain shelters were used to cover the plants during rain, and were removed as soon as rainfall ceased. Calibrated rain gauges were installed at the center and corners of the experimental area in case of shelter failures and/or drift of rainfall. Surface drainage was constructed around the area to prevent rain water from running under the shelter and into the lysimeters.

Cultural Practices

The buffer and lysimeter areas were planted with bahiagrass *(Paspalum notatum)*. Weeds were controlled by hand in the lysimeters that received treatments without grass cover. Grasses in the lysimeters that received treatments with grass cover were clipped to a height of 15 cm when the grass got taller than 30 cm. The grasses in the buffer area were irrigated by hand and mowed when necessary.

Citrus trees were transplanted bare root into the lysimeters. First side-dressing fertilizer was applied two weeks after planting, and then every month with compound fertilizer, 6 : 6 : 6 (N : P_2O_5 : K_2O) plus 1.0% Mg, 0.02% B, 0.05% Cu, 0.3% Fe, 0.1% Mn and 0.1% Zn at the rate of 0.5 kg per tree by broadcast.

Malathion was applied for insect control as needed. Other management practices were followed according to the Institute of Food and Agricultural Science recommendations (Julian and Jackson, 1980). The trees were allowed to recover for one month. The actual experiment was started in September and ended in December, 1984.

Treatments

This experiment was arranged in a completely randomized design with factorial treatments. It consisted of 6 different treatment combinations (3 levels of soil water potential (SWP) and 2 levels of ground cover), replicated four times. The treatments were

10G = − 10 kPa soil water potential with grass cover.
20G = − 20 kPa soil water potential with grass cover.
40G = − 40 kPa soil water potential with grass cover.
10Ng = − 10 kPa soil water potential without grass cover.
20Ng = − 20 kPa soil water potential without grass cover.
40Ng = − 40 soil water potential without grass cover.

Each lysimeter was irrigated independently at predetermined soil water potentials of − 10 kPa, − 20 kPa and − 40 kPa which is equivalent to 24%, 44% and 50% soil water depletion from field capacity level, respectively *(Figure 1)*..Field capacity was considered to be − 5 kPa SWP

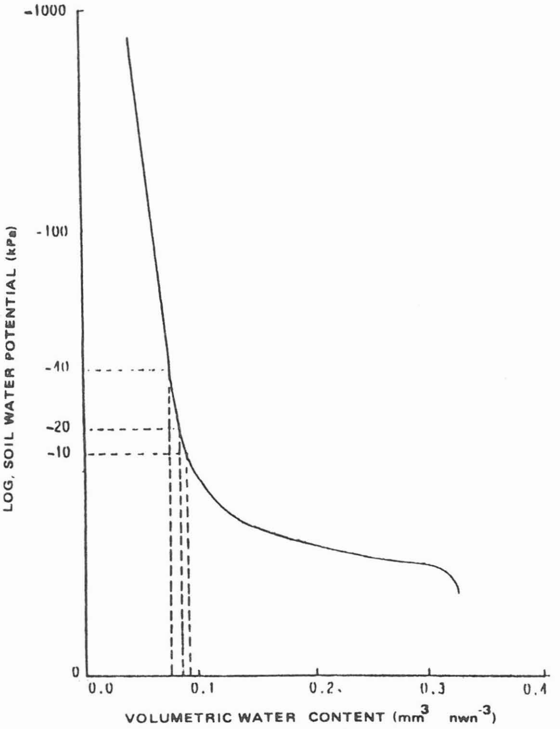

Fig. 1: The relationship between water content and soil water potential of Arredondo fine sand (Clark, 1982).

which corresponded to $0.11 \ mm^3 \ mm^{-3}$ soil water content.

Irrigation System

Calibrated automatic tensiometers were used to initiate irrigations. Each lysimeter had switching tensiometers located at depths of 15 cm, 30 cm and 60 cm *(Figure 2)*. The tensiometers were serviced every 2 weeks (Smajstrla *et al.*, 1981) or as required by the presence of air bubbles in the tensiometer tubes.

The amount of water applied was controlled using an automatic timer-controller. Instrumentation for the automatic irrigation control with tensiometers is described by Smajstrla *et al.* (1981). The automatic timer-controller was set to irrigate for a period of 4 minutes, 6 minutes and 7 minutes for irrigation initiated at −10 kPa, −20 kPa and −40 kPa SWP, respectively. Fifteen emitters were used per lysimeter to wet the soil in one dimensional manner at the rate of 270 mm h^{-1} and applied 7.0 mm, 12.0 mm and 14.0 mm depth of water per cycle for treatments −10 kPa, −20 kPa and −40 kPa SWP, respectively.

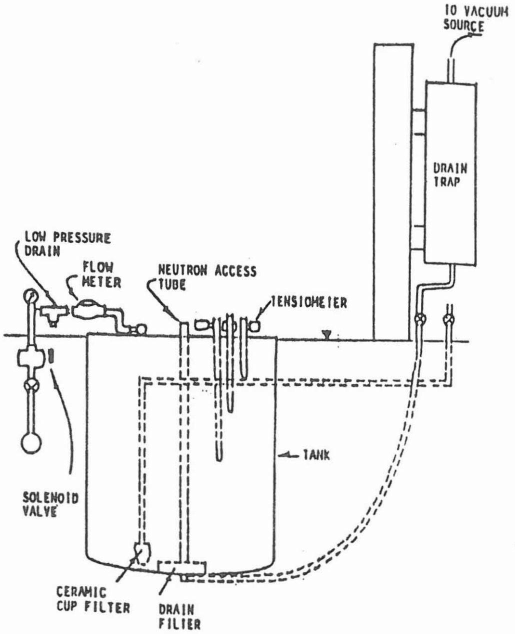

Fig. 2: Details of individual lysimeter soil water status monitoring system.

Actual Evapotranspiration

The amount of actual evapotranspiration of the trees at different soil water potential were calculated using the following water balance equation:

$$ET = I + P - D - \Delta S \qquad (1)$$

where ET = actual evapotranspiration (mm),
P = amount of precipitation (mm),
I = amount of irrigation (mm),
D = amount of drainage (mm)
ΔS = changes in soil water storage (mm).

The amount of irrigation applied to each lysimeter was recorded on a small calibrated impeller flow meter. Irrigation events for each lysimeter were recorded on a 24-channel event recorder.

The amount of drainage was measured with calibrated water trap cylinders. They were operated by a vacuum system which operated continuously to extract water from the bottom of the lysimeters. It was set to extract water to field capacity at the bottoms of the lysimeters.

Changes in soil water storage were calculated based on the soil water contents measured weekly. A neutron probe was used to measure volumetric water contents from 30 cm to 150 cm depths in 30 cm increments. The following calibration curve was used to calculate the volumetric water content:

$$\theta = 37.00CR - 3.31 \qquad (2)$$

where θ = percent volumetric water content, and

CR = the ratio of one-minute measured count and standard count with the probe in the shield.

Soil water content in the top 15 cm was measured with a surface moisture-density gauge, Troxler Model 3411-B. One-minute readings were taken with the radioactive source placed at the backscatter position. Details of the instrument specifications and capabilities were given by Troxler Electronic Laboratories (1979) and Smajstrla and Clark (1981).

The following equation was used to calculate percent volumetric water content:

$$\theta = \frac{W \times BS \times 100}{BW} \qquad (3)$$

where θ = percent volumetric water content,

W = computed soil water content (kg/kg),

BS = oven dry soil bulk density (kg/m^3), and

BW = density of water (kg/m^3).

Potential Evapotranspiration

Daily potential evapotranspiration rates were calculated based on the modified Penman equation as given by Jones *et al.* (1984) using short grass as the reference crop. The modified Penman equation is as follows:

$$ET_p = \frac{\Delta}{\Delta + \delta} \left[(1 - \alpha) R_s - T^4 \sigma (0.56 - 0.08 \sqrt{E_d}) \left(1.42 \frac{R_s}{R_{so}} - 0.41\right] / \lambda + \frac{\delta}{\Delta + \delta} \left[(0.263)(E_a - E_d)(0.5 + 0.0062 U_2) \right] \qquad (4)$$

where ET_p = potential evapotranspiration rate (mm/day),

Δ = slope of the saturation vapor pressure-temperature curve (mb/°C),

σ = Stefan-Boltzmann constant (11.71×10^{-8}cal/cm^{2}day/k)

δ = psychrometric constant (mb/°C),

R_s = total incoming solar radiation (cal/cm^{2}day),

R_{so} = total daily cloudless sky radiation (cal/cm^{2}day),

λ = latent heat of vaporization of water (cal/cm^3),

U_2 = wind speed at 2 meter height (km/day),

E_a = saturated vapor pressure, man of values obtained at daily maximum and daily minimum temperature (mb),

α = albedo or reflectively of surface for R_s, and

E_d = vapor pressure at dewpoint temperature (mb). The detailed description of the parameters used was given by Jones *et al.* (1984).

The weather data used in calculating potential evapotranspiration was obtained from the Irrigation Park weather station located about 50 m south of the experimental area.

Crop Water Use Coefficients

Crop water use coefficients were calculated based on the following equation as described by Doorenbos and Pruitt (1977) and Wright (1981):

$$K_c = \frac{ET}{ET_p} \qquad (5)$$

where K_c = dimensionless crop water use co-coefficient for young citrus trees,

ET = crop evapotranspiration from well-watered treatment (−10 kPa treatment) (mm/day), and

ET_p = potential evapotranspiration determined by Penman's method (mm/day).

Monthly K_c values were calculated from weekly measured ET and daily ET_p summed over a month.

RESULTS AND DISCUSSION

Daily Young Citrus Evapotranspiration

Evapotranspiration for grass cover treatments and potential evapotranspiration (ET_p) are graphed versus time in *Figure 3*. Evapotranspiration data were calculated using the water balance method given in equation (1). Potential evapotranspiration was calculated using the modified Penman method as given in equation (4).

During the research period, ET_p was greatest in September, being 3.26 mm day^{-1} in October, 1.75 mm day^{-1} in November, and 1.64 mm day^{-1} in December which is equivalent to 6.50 L/day, 3.50 L/day and 3.30 L/day respectively. Decreased ET_p were related to decreased net radiation. Evapotranspiration followed a similar pattern as ET_p, that is, ET greatest in September and lowest in December and were significantly different at the 0.05 level. These results were in close agreement with the results obtained by Pallas *et al.* (1967), who found that transpiration correlated positively with radiation level.

Young citrus ET with grass cover for the three SWP studied did not exceed ET_p *(Figure 3)*. The magnitude of young citrus ET was directly related to SWP. More water was required to maintain the root zone at Lower SWP. Vznuzdaev (1968) reported that transpiration rates decreased in direct proportion to SWP. Lower ET rodes at the low SWP studied were probably due to decreased mobility of water and its decreased availability to plants.

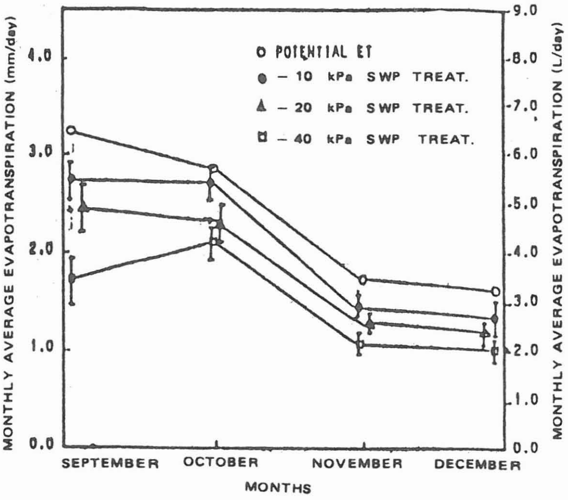

Fig. 3: Monthly average potential and actual evapotranspiration rates for young citrus trees with grass cover as a function of soil water potential. Vertical bars represent ± standard deviations.

Figure 4 shows the time series of young citrus ET with no grass cover, with respect to different SWP. Each data point represents the mean of four measurements. The effect of SWP on ET, showed a similar ET pattern under grass cover treatments, that is, ET decreased steadily from greatest in September to lowest in December, and ET decreased as SWP decreased. All the treatments were not significantly different at the 0.05 level.

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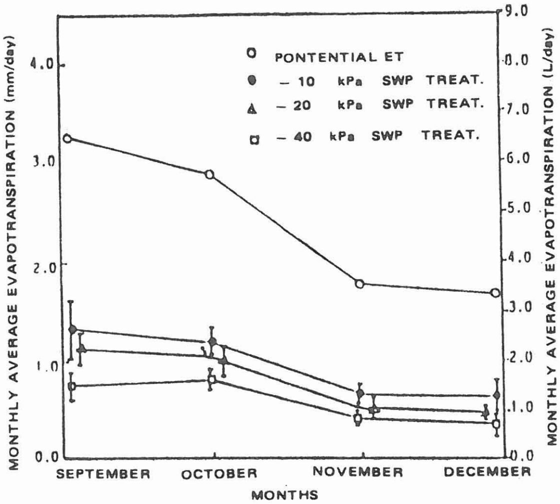

Fig. 4: Monthly average potential and actual evapotranspiration rates for young citrus trees without grass cover as a function of soil water potential. Vertical bars represent ± standard deviations.

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According to Peters (1960), if evaporative demand was less, one would expect the changes in ET to be less sensitive to SWP. Veihmeyer *et al.* (1960) found that, under lower evaporative demand that occurs in early spring in California, reduction in ET was small as the soil dried. This is in agreement with the results obtained from this research.

Fifty percent reduction in ET in no grass cover treatments were probably due to the mulching effect of the surface soil as it dried. This finding was in agreement with Tanner and July (1976). With low Leaf Area Index, evaporation comprises a large fraction of the total ET. At low surface water contents, evaporation rates might decrease in proportion to the water content remaining in the soil. As the surface becomes relatively dried, evaporation becomes proportionate to the rate at which water was brought up into the surface soil by capillary action. Eventually, a surface mulch will formed as a result of capillary break, thus greatly reducing the evaporation and consequently the ET rate.

Increased water-use under grass cover conditions emphasized the advantages of clean-cultivation over grass-cover groves. Elimination of grass appears to have potential in reducing ET from young citrus groves. Increased water use when irrigated at high SWP, suggests the importance of irrigating a rate no higher than necessary for the degree of growth desired and to minimize deep percolation losses.

Crop Water Use Coefficients

Figure 5 shows the time series of crop water use coefficients (Kc) with respect to different treatments and under different lysimeter ground covers: grass and no grass. Monthly average Kc values from well-watered treatments were used to indicate monthly young citrus Kc for the purpose of estimating crop water requirements.

Crop water use coefficients of young citrus trees with grass cover treatments were 50% higher than with no grass cover treatments. Larger differences in Kc *(Figure 5)* were likely due to the variation in the evaporation rate from the soil surface and from the grass cover itself. Frequent irrigation under grass cover conditions resulted in higher soil water content in the top layer. Therefore, water was more readily available for ET.

Crop water use coefficients were influenced by SWP and ground cover conditions. As shown in *Figure 5*, Kc values decreased as SWP decreased. This was apparently due to a decrease in ET as a result of increasing resistance to water flow through the Soil-Plant-Atmospheric-Continuum as SWP decreased. A small decrease in Kc toward the end of the research period in November and December were apparently due to less active growth of young citrus trees during a period of cool weather. Treatments 40G and 40NG exhibited a larger decease of Kc in Sep-

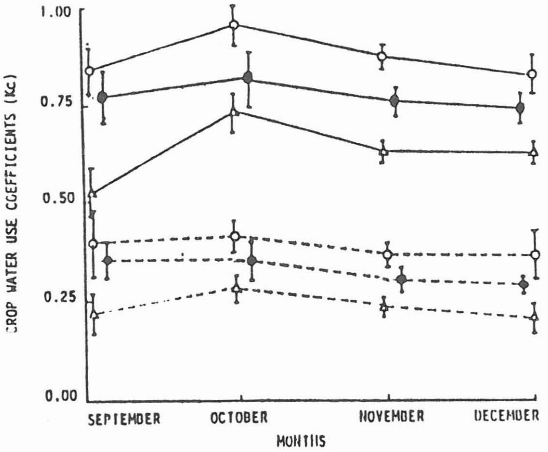

Fig. 5: Monthly average young citrus water use coefficients with grass and no grass cover conditions (—O—10G, —●— 20G, — — 40G, --O-- 10NG, --●-- 20NG, -- --40NG). Vertical bars represent ± standard deviations.

tember, during a period of higher ET_p. According to Smajstrla (1982) the ratios of ET and ET_p were logarithmically distributed as a function of time when ET_p was fairly constant. Denmead and Shaw (1962) showed that the SWP at which the ratio of ET and ET_p decreased from a maximum depends on the ET_p. They found that ET decreased below ET_p of 3 – 4 mm day^{-1} when SWP in the root-zone was about – 200 kPa. On the other hand, when ET_p was 6 – 7 mm day^{-1}, ET decreased below the ET_p when SWP was about – 30 kPa. This finding agreed with those results.

Crop water use coefficients can be used as a guide for other locations and other years with different climatic conditions, provided soil type, stage of growth and irrigation management are similar. Crop water use coefficient values for no grass cover condition could be used to calculate young citrus ET which has grass in between the trees and bare soil around it. Crop water use coefficients of young citrus with low Leaf Area Index published elsewhere (Doorenbos and Pruitt, 1977) indicated slightly higher Kc. These differences could be due to differences in soil type, and the number of irrigations.

CONCLUSION

During the research period, ET_p was highest in September, about 3.26 mm day^{-1}, and lowest in December, about 1.64 mm day^{-1}, with a decreasing trend from month-to-month. Young citrus ET was lower than the ET_p. Amounts of ET for no grass cover treatments were significantly less than grass cover treatments. In general, the increase in ET under grass cover was more than 50%.

Crop water use coefficients varied as a function of SWP and grass cover conditions. Crop water use coefficients were highest for high SWP treatments, during the period of highest evaporative demand, and under grass cover conditions.

The following conclusions can be drawn from this experiment:

1. Young citrus with grass cover required considerably more water to meet the evaporative demand compared to no grass cover. Therefore, if water supply is limited, clean cultivation should be considered to reduce the irrigation requirements.
2. Crop water use coefficients were influenced by SWP and ground cover conditions. Crop water use coefficients decreased with decreasing SWP, during cool weather, and under no grass cover conditions.

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