FIRST YEAR EFFECTS OF CONTROLLED DEFICIT IRRIGATION ON WALNUT TREE PERFORMANCE

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ABSTRACT

The response of conventionally-spaced cv. Chico walnuts to controlled deficit irrigation (CDI) was evaluated for the first year in 1989. CDI strategies are important in drought years when water supply is limited and are designed to apply the most water during the critical tree and fruit growth stages. Assuming that only 16 inches of total water was available, the CDI regime test applied nearly full irrigation through early May followed by progressively smaller percentages of potential orchard water use.

While dramatic reductions in CDI tree water status and apparent carbon assimilation were observed by mid June and for the remainder of the season, there were no significant differences in current season yield or nut size. Trunk growth rates were significantly reduced throughout the season as was canopy size. This suggests less bearing surface next year with consequent negative impacts on yield.

OBJECTIVES

This project was initiated to evaluate the effects of a controlled deficit irrigation (CDI) regime on current and subsequent years' tree growth and productivity. It was designed to simulate drought conditions that limit a grower's water supply to only 16 inches for the season and evaluate the impact on short and long term tree performance of applying water based on our best recommendations for a CDI regime.

This report covers the first year results of the CDI. We plan to return this year's stressed trees to full irrigation next year and evaluate the recovery of these trees under two pruning regimes.

PROCEDURE

Conventionally spaced (22 x 22 ft) cv. Chico trees at the Kearney Ag. Center planted in early 1982 and grown under full irrigation were used in this study. Our previous work shows that tree growth, nut expansion, and stomatal aperture reach their maximum by early June. Thus, the CDI strategy was designed to apply relatively large amounts of water early in the season and progressively less as the season advanced. The CDI regime was based on applying certain percentages of estimated ETc and is summarized in Table 1. Note that only 25% ETc was applied from July 1 through harvest. Since previous water stress work showed that cv. Chico is extremely tolerant of heat-related kernel injury (sunburn), we were not concerned about late season stress although this may be a problem with more heat-sensitive walnut cultivars.

A randomized complete block design was used with three replications of three treatments, which included two sets of the CDI treatment. The original plan was to stress trees for both one and two years followed by return to full irrigation. However, tree variability was such that the second set of CDI trees could not be used in any comparison with the nonstressed trees and will be reserved for the future pruning/irrigation recovery work. Each plot contains eight trees on which measurements were made. Plots are isolated with respect to irrigation treatments by heavy wall polyethylene sheeting that is installed to a depth of 4 ft midday between trees.

Water is applied using circular low volume sprinklers positioned in the tree rows 5.5 ft. from the tree. Orchard water use (ETc) is estimated from reference crop water use (ETo) and previously determined crop coefficients (Kc). Applied water is measured with meters on each plot and monthly application amounts are shown in Figure 1.

Predawn leaf water potential and midday stomatal conductance measurements were taken periodically with a pressure chamber and steady-state porometer, respectively. The former measurements were taken on single leaves on each of four trees per replication (12 per irrigation regime) and three leaves on each of the same trees (36 per irrigation regime) were monitored for the latter measurement. On June 21, July 26, and September 6, diurnal measurements of leaf water potential, stomatal conductance, and canopy temperature (using a hand-held infrared thermometer on top of a ladder and pointed at the tree slightly below horizontal) were taken. Radial trunk growth was measured periodically over the season on eight trees per plot. Canopy size was assessed in late August by determining the shaded areas of the orchard floor at 1:00 p.m. Neutron probe measurements to assess soil water were made periodically on access tubes located in both irrigated (tree row) and dry (drive row) locations. Leaf brushing to evaluate mite levels was conducted periodically over the season.

The orchard was harvested on September 7 with a commercial shaker and individual tree weights were determined. Composite nut samples for each plot were taken, dried, and delivered to Diamond Walnut Growers, Inc. for analysis of nut component weights (shell and kernel), size (commercial classifications), and quality.

RESULTS AND DISCUSSION

<u>Seasonal tree water status and stomatal behavior</u>

Predawn leaf water potential directly reflected the differences in applied water between the two irrigation regimes (Figure 2). With the exception of late May and early June when a water supply line break at the field station resulted in no irrigation for a week, predawn values at 100% ETc generally did not exceed about -0.3 MPa (1 MPa is 10 bars). On the other hand, CDI predawn values decreased gradually over the season, reaching about -1.0 MPa before harvest.

Midday stomatal conductance was more dramatically affected by the CDI (Figure 3). After late May, midday CDI stomatal conductance decreased rapidly over the season reaching 0.1 cm/sec before harvest while values remained about 1.0 cm/sec throughout the season for the 100% ETc trees.

Diurnal plant-based measurements

While three sets of diurnal measurements were taken, only the July 26 monitoring will be reported herein in the interest of brevity. Leaf water potential, stomatal conductance, and canopy temperature measurements made every two hours from 4:30 a.m. to 8:30 p.m. are shown in Figures 4-6. Distinct separations are evident between treatments throughout the day. At 100% ETc, leaf water potential decreased from -0.2 MPa to about -1.0 MPa at 10:30 a.m. and remained constant until 2:30 p.m. when it began to recover (Figure 3). For the CDI, a predawn value of about -0.8 MPa was followed by midday readings of about -1.4 MPa and the diurnal CDI values followed the same pattern as the control.

At 100% ETc, a maximum stomatal conductance value of about 1.2 cm/sec was reached at 10:30 a.m. followed by a slow decline to 0.7 cm/sec at 4:30 p.m. (Figure 5). The CDI trees had a maximum stomatal conductance at 8:30 a.m. of only 0.3 cm/sec which declined slowly over the day to 0.15 cm/sec at 4:30 p.m. This clearly suggests that carbon assimilation was dramatically lower with the CDI as the trees attempted to maintain their internal water status by closing the stomata.

Canopy temperatures reflected the large differences in canopy transpiration (and thus cooling) indicated by the stomatal conductance measurements (Figure 6). Separation was between 2 and 4 °C throughout the day. Maximum canopy temperature of 35 °C in the CDI trees was observed at 2:30 p.m. and remained constant until 4:30 p.m. This compares with maximum 100% ETc values of about 32 °C during this period. It should be noted that diurnal canopy temperature measurements taken at other times during the year also showed this plateau in maximum readings during the above time period.

Trunk growth and canopy development

Radial trunk growth rates peaked in early June (Figure 7) for both irrigation treatments but the maximum CDI growth rate was reduced by about 60% relative to the control (0.029 vs. 0.072 mm/day). Significantly reduced trunk growth rates in the CDI trees occurred over the entire season. The dramatic reduction in the rate of trunk growth suggests less shoot and branch growth which may affect the following year's fruit load.

Canopy development expressed as the amount of shaded area of the orchard floor was significantly lower with the CDI, as shown in Table 2. This is consistent with the observation of reduced trunk growth and also indicates that future nut production may suffer due to lower bearing surface.

Soil water

Soil water profiles measured in the area wetted by the low volume sprinklers in mid July for each irrigation regime are shown in Figure 8. Throughout the profile, CDI levels were lower. It should be noted that the shallowest measurement was taken at the 9 inch depth and it's likely that CDI soil water levels in the top 6 inches may have been higher. Higher frequency, deficit irrigation clearly depletes all soil water reserves in the profile as the applied water is immediately used by the trees.

Nut yield and fruit load

Harvest yields were not significantly different between the CDI and full irrigation regimes (Table 2). Even though CDI fruit load (number of nuts per tree) was slightly higher, the yield was marginally lower. This is explained by the lower average CDI individual nut weight which although not significantly different, was about 12% less than the control. Kernel percentage was not affected by the irrigation treatments.

Commercial nut size classifications were not significantly different (Table 3). However, the trend was clear -- fewer large nuts with the CDI (Jumbo and Large sizes accounted for 30.6% of the CDI fruit load vs. 52.3% for the control).

Nut quality

Edible yield, internal damage of the large sound nuts, and reflective light index (kernel color) were not significantly different between treatments (Table 4). Consistent with the nut size category breakdown data, the percentage of large sound nuts was greater with the control but did not pass the test for significance. However, offgrade and insect damage was significantly greater for the CDI nuts, although no differences were observed in mite levels in the orchard.

CONCLUSIONS

The CDI did not significantly affect any of the major yield components for the current year. However, trunk growth rates and canopy size were significantly reduced. This suggests possible effects on the following season's crop load.

It's clear that a severe reduction in water supply severely impacts on tree water status, carbon assimilation, and growth. Our optimized CDI regime was designed to limit these effects to less critical growth periods. Continued monitoring is needed to assess carryover effects on future orchard productivity.

Table 1. Controlled deficit irrigation (CDI) strategy used to apply 16 inches of water for the season.

Period	Applied (% ETc)
through March 15	0
March 16 - April 30	85
May 1 - May 15	75
May 16 - May 31	65
June 1 - June 30	50
July 1 - September 7 (harvest)	25
Postharvest	0

Table 2. Harvest, fruit load, and canopy-growth related data.

Treatment	Yield dry in-shell[1] (lbs/tree)	Fruit load (nuts/tree)	Individual nut weight[2] (gm/nut)	% Kernel	Shaded area[3] (%)
100% ET_c (full irrigation)	49.0	2263	9.23	48.8	58.1 a
Controlled Deficit Irrigation	44.8	2381	8.15	47.2	45.1 b
	NS	NS	NS	NS	*

1/ 8% water content by weight.
2/ Oven dry.
3/ Orchard floor measurements on Aug. 30, 1989.

* Asterisk beneath columns indicates significant differences at the 5% confidence level between numbers followed by different letters. NS indicates no significant differences in the column.

Table 3. Commercial nut size categories.

Treatment	Jumbo	Large	Medium	Baby
	---------------	% by #	---------------	
100% ET (full irrigation)	25.8	26.5	23.5	24.2
Controlled Deficit Irrigation	12.9	17.7	36.4	33.0
	NS	NS	NS	NS

* NS beneath columns indicates no significant differences at the 5% confidence level.

Table 4. Commercial harvest quality parameters.

Treatment	Edible yield[1/]	Large sound1/	Off-grade[2/]	Internal damage[3/]	Insect damage[1/] (% by #)	RLI #1[4/]
	-------------	% by weight	-------------			
100% ETc (full irrigation)	48.2	54.0	0.8 a	1.03	0.3 a	37.3
Controlled Deficit Irrigation	45.0	22.2	4.0 b	2.6	2.3 b	36.8
	NS	NS	*	NS	*	NS

1/ Of tree nut load.
2/ Of kernels.
3/ Of large externally sound nuts.
4/ Reflective Light Index. The higher the RLI, the higher the kernel color.

* Asterisk beneath columns indicates significant differences at the 5% confidence level between numbers followed by different letters. NS indicates no significant differences in the column.

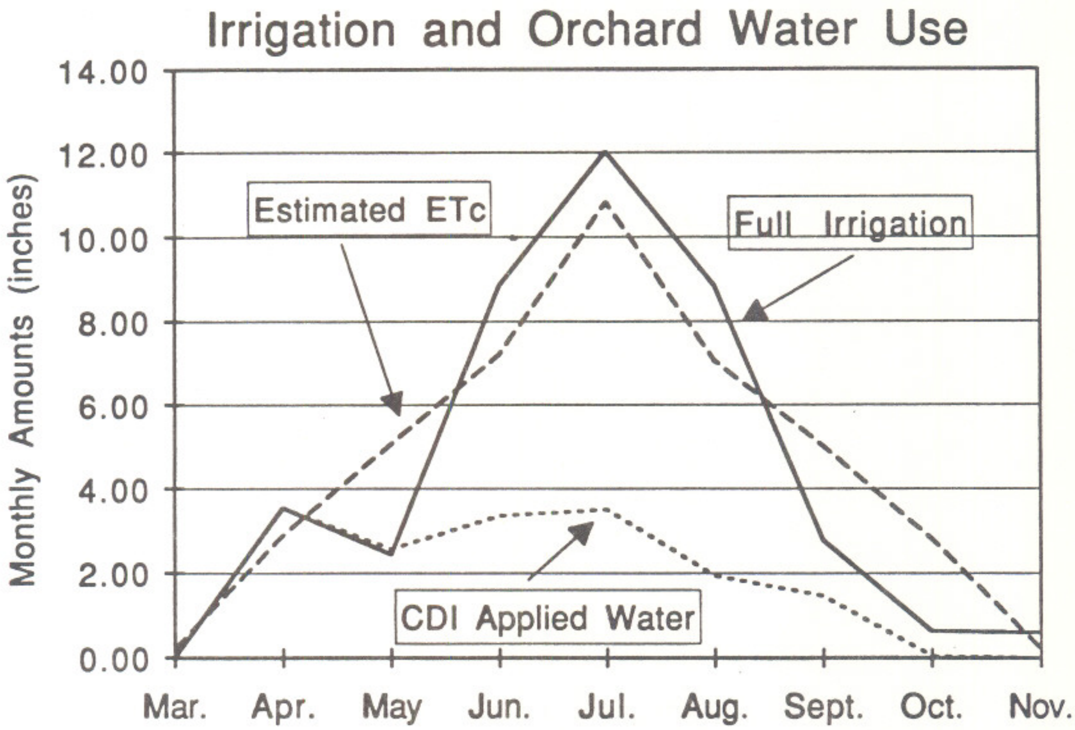

Figure 1. Monthly amounts of applied water and estimated potential orchard water use.

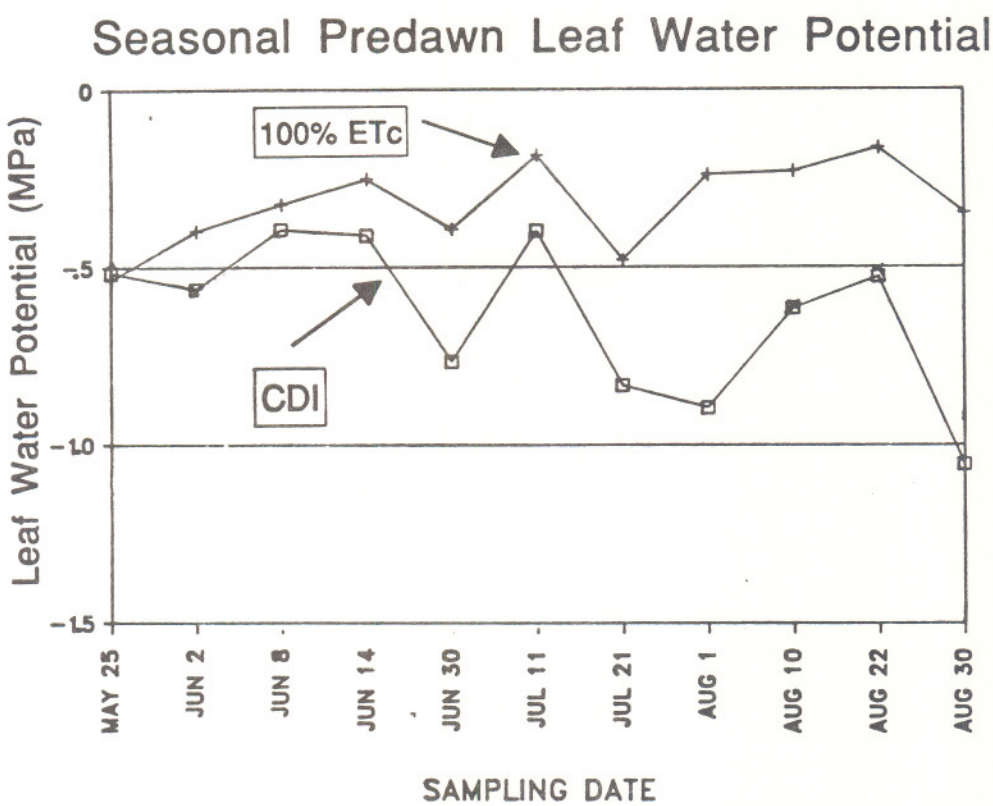

Figure 2. Predawn leaf water potential over the season.

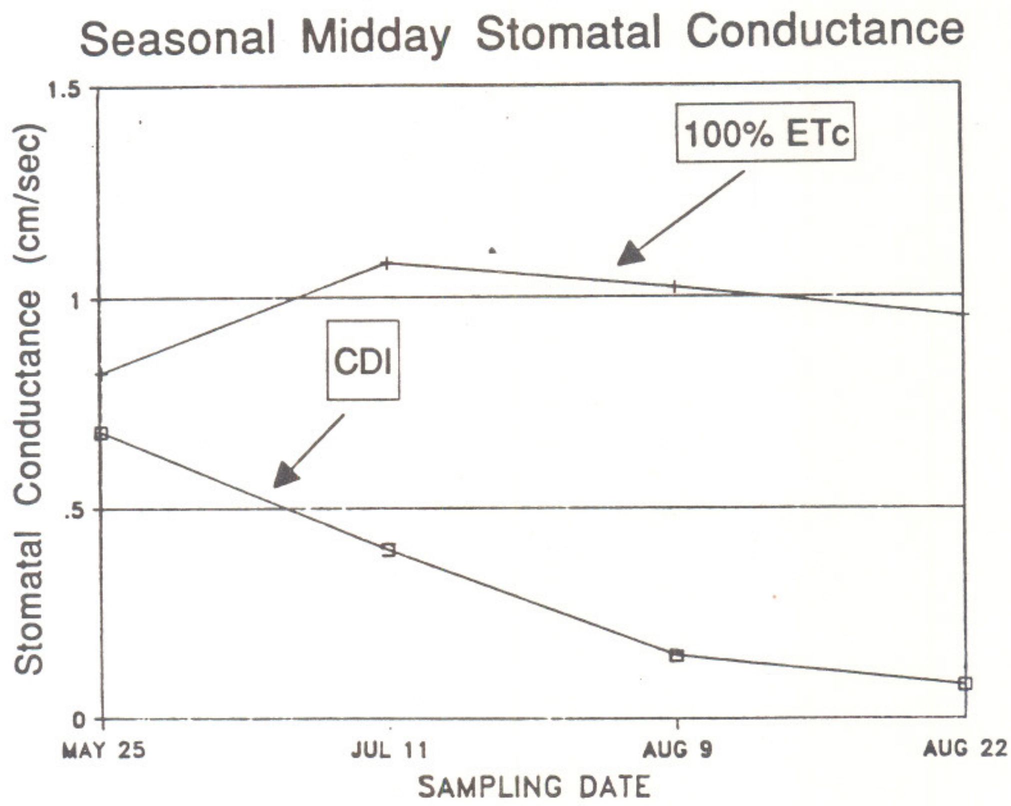

Figure 3. Midday (1:00-2:00 p.m.) stomatal conductance over the season.

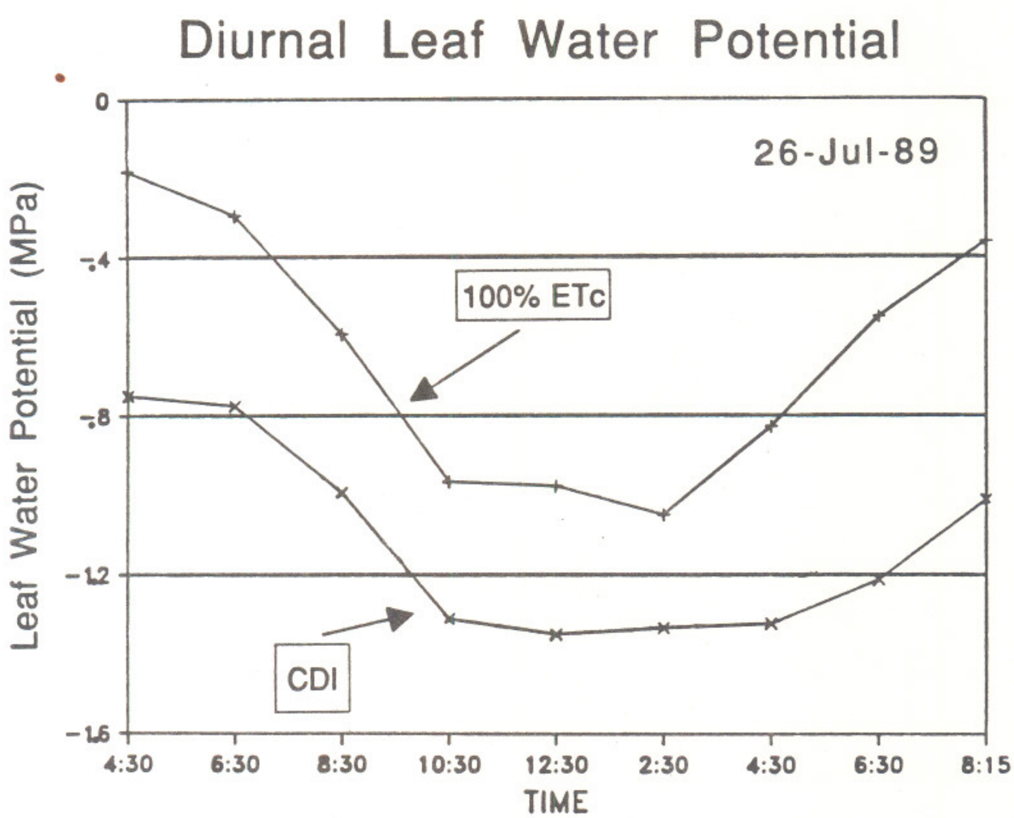

Figure 4. Diurnal leaf water potential on July 26, 1989.

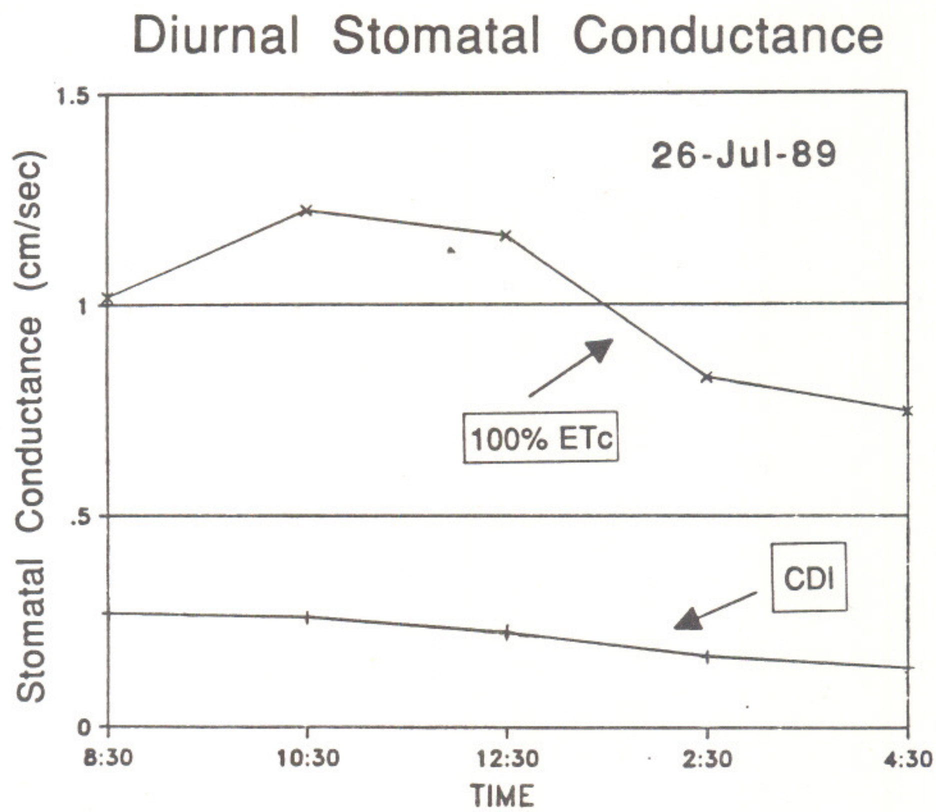

Figure 5. Diurnal stomatal conductance on July 26, 1989.

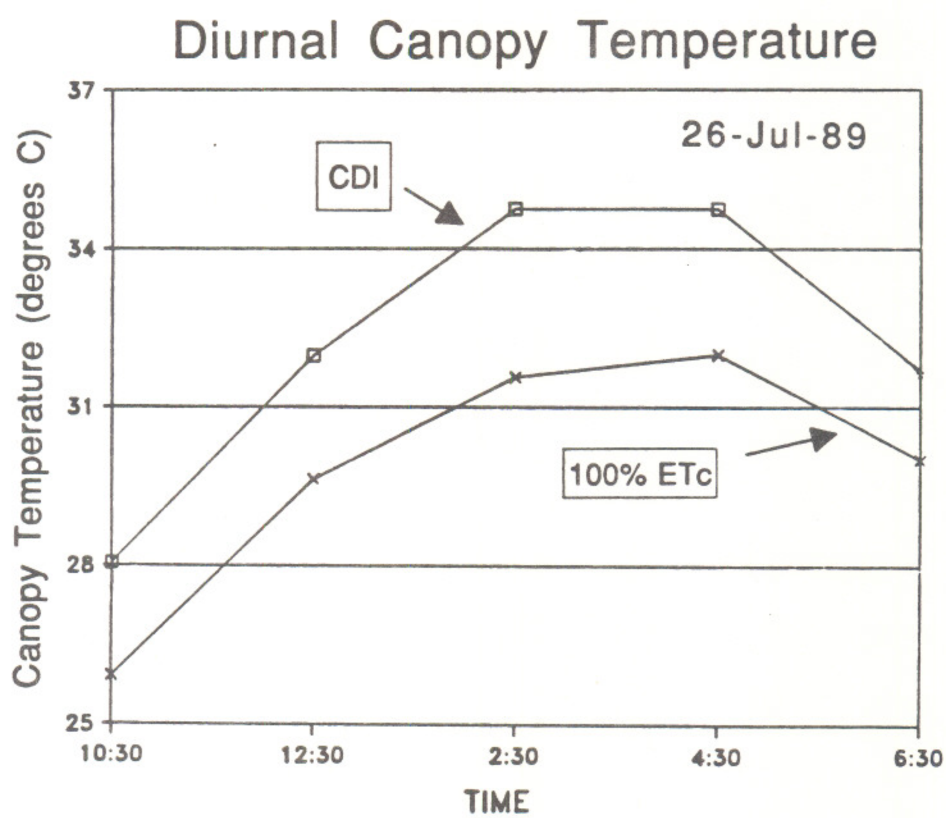

Figure 6. Diurnal canopy temperature on July 26, 1989.

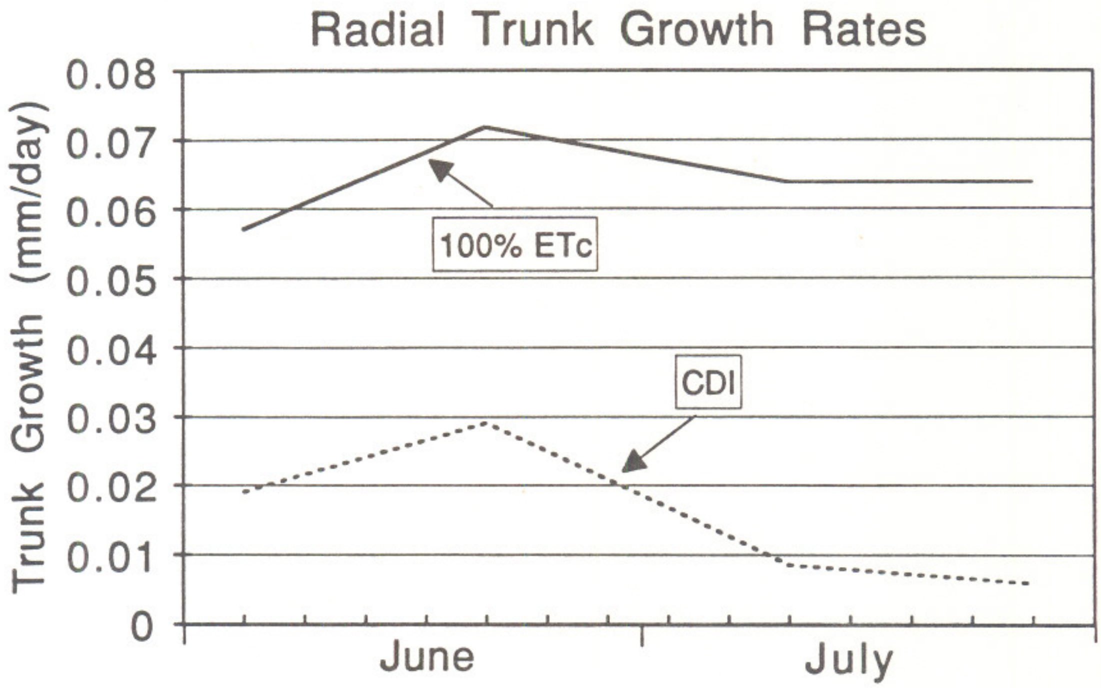

Figure 7. Radial trunk growth rates over the season.

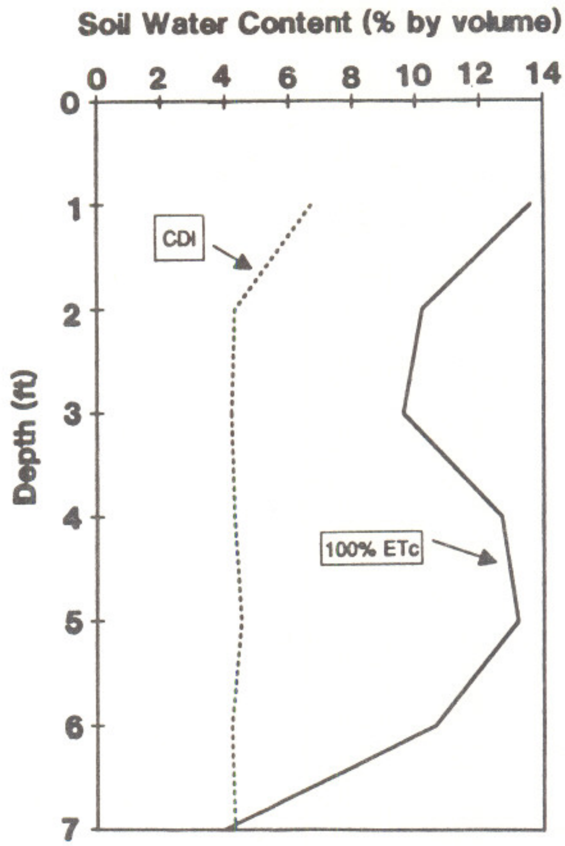

Figure 8. Soil water content profiles on June 20, 1989.