Water Relations of High and Conventional Density Walnuts

D. A. Goldhamer, B. C. Phene, R. Beede, T. M. DeJong, D. Ramos, J. Doyle

ABSTRACT

Field studies continued in 1986 to evaluate the water use requirements of hedgerow (11 x 22 ft) and conventional (22 x 22 ft) density walnuts. Additionally, a deficit irrigation study was begun this season to investigate the effects of plant water stress on tree performance. This work showed tree growth (canopy development and radial trunk expansion) was the most water stress sensitive plant process, although nut size was also affected. The first year of water deprivation only modestly reduced dry in-shell yield, presumably due primarily to nut size differences rather than fruiting densities.

Yields of the fifth year trees were 620 and 2304 lbs/acre (8% moisture) in the conventional and hedgerow plantings, respectively. This factor of four difference is less than the 6-fold differences observed in the previous two seasons. Nut size and most other quality parameters in the conventionally-spaced trees were equal or better than those of the high density trees.

OBJECTIVES

A number of long term goals have been established for this continuing project involving hedgerow and conventional walnut tree spacings: (1) to determine the crop evapotranspiration (ET) from planting to orchard maturity, (2) to determine relationships between developing orchard ET and tree productivity, and (3) to evaluate effects of plant water stress on tree performance.

In 1986, we initiated the study to evaluate deficit irrigation response.

PROCEDURE

This work is being conducted in a five year-old block of 'Chico' trees located at the Kearney Agricultural Center in Fresno County. A 2.5 acre orchard is divided into high (11 x 22 ft) and conventional (22 x 22 ft) density sections, each equipped with independent low volume sprinkler systems for controlled water management. The sprinklers are positioned in the tree rows 5.5 ft from each tree and apply water in a circular pattern.

In 1986, three irrigation treatments were initiated in the high density section by applying approximately 100, 66 and 33% of the calculated ET. The experimental plots are laid out in a completely randomized design with three replications. Each replication consists of 4 x 6 trees with the outside tree in each direction being a guard tree.

All plots are irrigated with the same frequency; two or three times per week. The differential water application is accomplished by using different size low volume sprinkler heads. In 1986, the irrigation scheduling in the high density was not adjusted to account for the degree of canopy cover as was done in the past when the trees were smaller. However, downward adjustment of calculated ET for the conventional density section trees was continued in 1986 based on canopy cover of the orchard floor.

Water applications in the conventional density section as well as in each replicated plot in the high density section were measured with water meters. Canopy development was evaluated by measuring the shaded area of the orchard floor at 1:00 p.m. at least once per month from May through October. Measurements were taken by counting the shaded squares of a grid matrix drawn on a tarp and placed beneath the trees.

Plant based response in the deficit irrigation study was monitored weekly at midday by leaf measurements of water potential and stomatal conductance. For each of these measurements, four trees per plot (12 trees per treatment) were evaluated. At mid-season (July 25), the diurnal changes in leaf water potential and stomatal conductance were monitored. Thus, plant water status was studied as a function of two time frames; throughout the season and throughout the day.

Radial trunk growth was measured on eight trees per plot in the high density section by means of repeated measurements with a microdendrometer. These measurements were taken twice monthly beginning February 28, 1986 and continued until December 5. Readings were taken in the morning to avoid trunk shrinkage associated with midday water stress.

In the conventional density section, measurements of leaf water potential, stomatal conductance and trunk growth were not taken in 1986.

The orchard was harvested on September 15 with a commercial shaker and individual tree field weights measured with a weighing nut buggy. Subsamples were collected in each plot and weighed, hulled, dried and reweighed. These subsamples were delivered to Diamond Walnut Growers, Inc. and analyzed for nut size (five category breakdown), and nut quality (offgrade, insect damage, internal and external damage, large sound, edible yield and reflected light index).

RESULTS AND DISCUSSION

Net water applications (including 3.22 inches rainfall) in the high density block totaled 35.9, 25.4 and 16.2 inches for the 100, 66 and 33% ET levels, respectively (Figure 1). ET was calculated weekly from reference evapotranspiration (ET_o) measured at a nearby weather station and estimates of mature walnut tree crop coefficients (K_c). Calculated seasonal ET totalled 39.8 inches. However, this does not take into consideration a small reduction in actual ET incurred at harvest due to shut down of the irrigation system to insure a dry soil surface for machinery traffic.

The crop water requirements in the conventional section were estimated to be 75% of full ET based on the percent shade at mid-season. This resulted in calculated seasonal ET of 29.8 inches. Net irrigation applied totalled 25.1 inches, and rainfall was 3.2 inches.

High density walnut canopy development is shown in Figure 2 as reflected by percent shade of the orchard floor as a function of time for each irrigation treatment. Summer pruning occurred on June 16 and explains the decrease in shade of all treatments between the first and second dates of measurement. Thereafter, orchard floor shading generally increased but at rates directly related to the irrigation treatments. The sensitivity of canopy development to water stress is particularly evident in the 66 and 33% ET treatments in July, a high evaporative demand time.

Table 1 shows dates of measurements and percent shade in the conventional section for 1986. Canopy cover in the conventional trees was considerably lower early in the season than that in any high density plot. However, rapid growth occurred thereafter and by October 13, shaded area was greater than 60% of the orchard floor.

Table 1. Conventional density canopy development, expressed as orchard floor shaded area throughout the 1986 season.

May 28	June 14	July 16	July 31	August 12	September 10	October 13
% shade						
28.5	28.3	35.5	43.9	44.7	52.6	62.3

Midday leaf water potential (LWP) is shown in Figure 3 for each deficit irrigation treatment. Throughout the season, there were relatively consistent, yet clearly different, LWP readings for each treatment. Leaf stomatal conductance (Figure 4), on the other hand, dramatically decreased with time in all treatments. With both measurements, a separation between treatments is evident by the end of May; less than 45 days after differential irrigations began.

Figure 5 shows leaf water potential and stomatal conductance for each treatment during the July 25 diurnal study. Consistent differences between treatments were recorded, particularly in leaf water potential. Stomatal conductance in the 33% ET treatment was greatest in the the early morning (8:30 a.m.) and never exceeded 0.80 cm/sec. The 66% ET treatment reached maximum leaf conductance in the mid-morning (10:00 a.m.) and remained relatively constant over the midday period. Under full ET, stomatal conductance was lowest in the early morning and increased continually through the morning hours, reaching a maximum of 1.26 cm/sec at 1:00 p.m. Thereafter, the 100% ET stomatal conductance decreased. The diurnal pattern of stomatal conductance in the deficit irrigation plots typifies behavior of water-stressed plants -- maximum opening during low evaporative demand times (early morning). In other words, the trees were making the best of a bad situation by assimilating CO_2 at a relatively fast rate while losing the minimum amount of water. While stomatal control resulted in the maintenance of a favorable plant water status during the midday hours, the tradeoff was presumably lower uptake of CO_2.

The relative magnitudes and duration of the tree water stress were reflected in reduced trunk radial growth in both the 33 and 66% ET treatments. Radial trunk growth rates and cumulative amounts are shown in Figures 6 and 7, respectively. Beginning June 4 (fifth measurement), the trunk growth rate of the 33% ET treatment was consistently less than that of the 66 and 100% ET treatments (Figure 5). Peak growth rate occurred during the first week of June in all treatments and subsequently dropped to zero, or even a contraction of trunk size, in October and November. Figure 7 illustrates that by July 1, cumulative trunk growth in the 33% ET treatment trailed that in the 66 and 100% ET treatments. A less severe response was observed in the 66% ET treatment which lagged the 100% ET trunk growth after August 8.

Table 2 shows the harvested dry in-shell size distribution expressed as the following categories:

(1) Jumbo (nut diameter greater than 80/64 inches)
(2) Large (nut diameter between 77/64 and 80/64 inches)
(3) Medium (nut diameter between 73/64 and 77/64 inches)
(4) Baby (nut diameter between 60/64 and 73/64 inches)
(5) Pee Wee (nut diameter less than 60/64 inches)

In the 100% ET treatment, 60.8% of the nuts ranked in the Jumbo classification, as compared to 51.6 and 45.4% in the 66 and 33% ET treatments, respectively. However, total dry in-shell yields varied little between treatments: 2304, 2291, and 2084 lb/acre at 8% water content for the 100, 66 and 33% ET, respectively.

Table 2. Walnut size distribution for the dry in-shell nuts in the 100, 66, and 33% ET treatments of the high density section at harvest.

	Walnut size classification				
Treatment	Jumbo	Large	Medium (percent)	Baby	Pee Wee
100% ET	60.8	19.8	13.7	5.5	0.2
66% ET	51.6	27.3	16.3	4.6	0.2
33% ET	45.4	26.1	19.1	9.2	0.2

Table 3 shows the results of the quality analysis in terms of large sound, edible yield, offgrade, insect damage, internal and external damage, and reflected light index (see footnote for explanation of sample size and description for each parameter). Again, the irrigation treatments resulted in little differences in walnut quality, particularly in the edible yield category. However, the differences that are apparent in the offgrade and internal damage categories reflect a decrease in quality in the 100% ET treatment. This was due primarily to a blackening of the kernals. The specific cause of the black kernals is unknown at this time.

Table 3. Walnut harvest quality for each irrigation regime.

Treatment	Large Sound* -- % by	Edible Yield* wt. --	Off-grade† % by wt.	Insect Damage§ -------	Internal Damage° % by number	External Damage+ --------	RLI++
100% ET	71.9	40.5	15.6	0.2	13.4	1.4	28.8
66% ET	73.1	42.3	10.4	0.6	8.4	2.0	31.7
33% ET	66.8	42.0	10.3	0.6	9.0	1.3	32.9

* Sample = dry in-shell yield
† Sample = dry kernal yield
§ % of total sample
° % of large externally sound
\+ % of large externally sound and damaged yield
++ Reflected light index

In the conventional section, a relatively large percentage of walnuts fell into the Jumbo and Large size categorites (83.4 and 6.7%, respectively). The remaining nuts were distributed between the Medium, Baby and Pee Wee categories as 5.9, 3.2 and 0.8%, respectively. However, the total yield was considerably less than any of the high density treatments at 620 lb/acre (dry in-shell at 8% water).

The walnut quality grading of three subsamples in the conventional section resulted in 82.0 and 42.9% by weight of large sound and edible yield, respectively. Offgrade dry kernal yield was 5.5%, and insect, internal and external damages were 0.4, 4.2 and 6.1% by number, respectively. In general, these gradings are equivalent or better than those in the high density section. However, the RLI reported for the conventional section was the lowest of all samples at 28.5.

CONCLUSIONS

Low volume irrigation was applied at 33, 66, and 100% ET to fifth year hedgerow walnuts that had been previously fully irrigated. Leaf water potential and stomatal conductance were generally reduced in proportion to the severity of the irrigation treatment. This resulted in reduced canopy and radial trunk growth as well as the size of dry in-shell nuts. This first year of water deprivation only modestly reduced dry in-shell yield, presumably due primarily to nut size differences rather than fruiting densities.

Fifth year conventionally spaced trees were not expected to yield or use water to the same extent as mature trees in a hedgerow planting. Total water applied in the conventional section was 28.3 inches. Dry in-shell yield was 620 lb/acre (8% water), 26.9% of that in the 100% ET treatment in the high density section. A relatively large percentage of the yield was sized as large or above; presumably due to the low fruiting density as compared to the hedgerow trees.

ACKNOWLEDGEMENTS

We appreciate the technical support of Lori Scherlin, Scott Mahan, Zerferino Cervantes, and Liz Kellogg in this study. We also express thanks to Diamond Walnut Growers, Inc. who graciously conducted the nut quality tests.

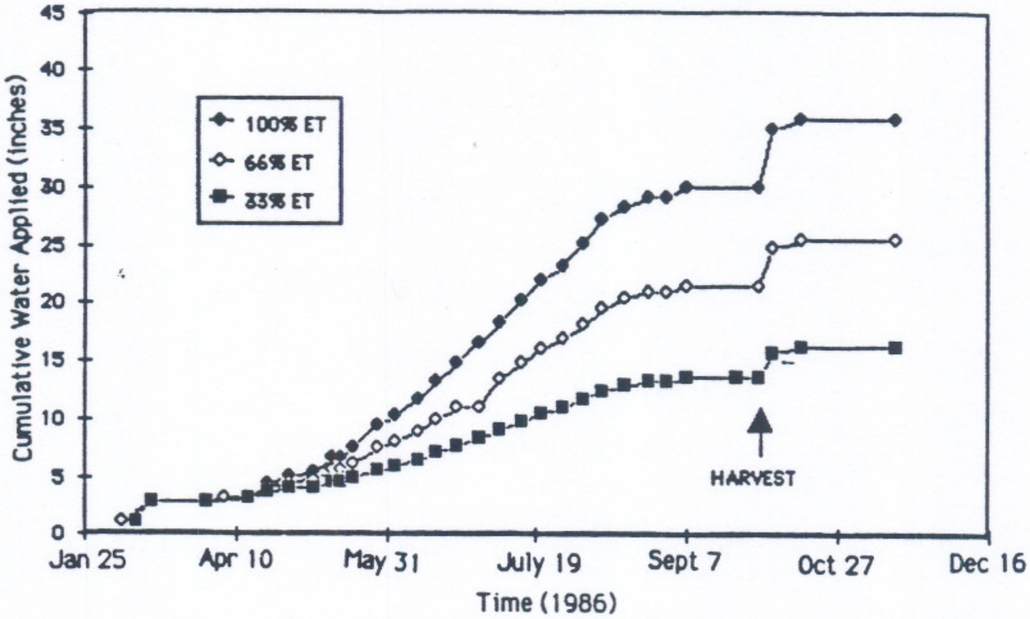

Figure 1. Cumulative water applied in each high density irrigation treatment for 1986.

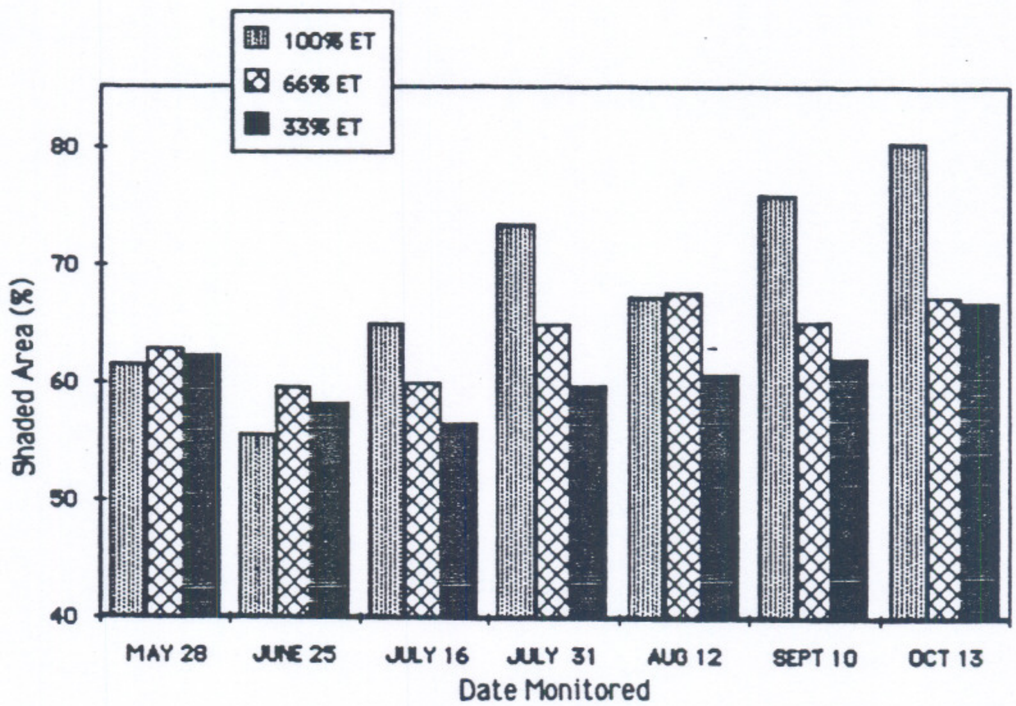

Figure 2. Canopy development of each irrigation treatment in the high density section as reflected by changes in shaded area throughout the 1986 season.

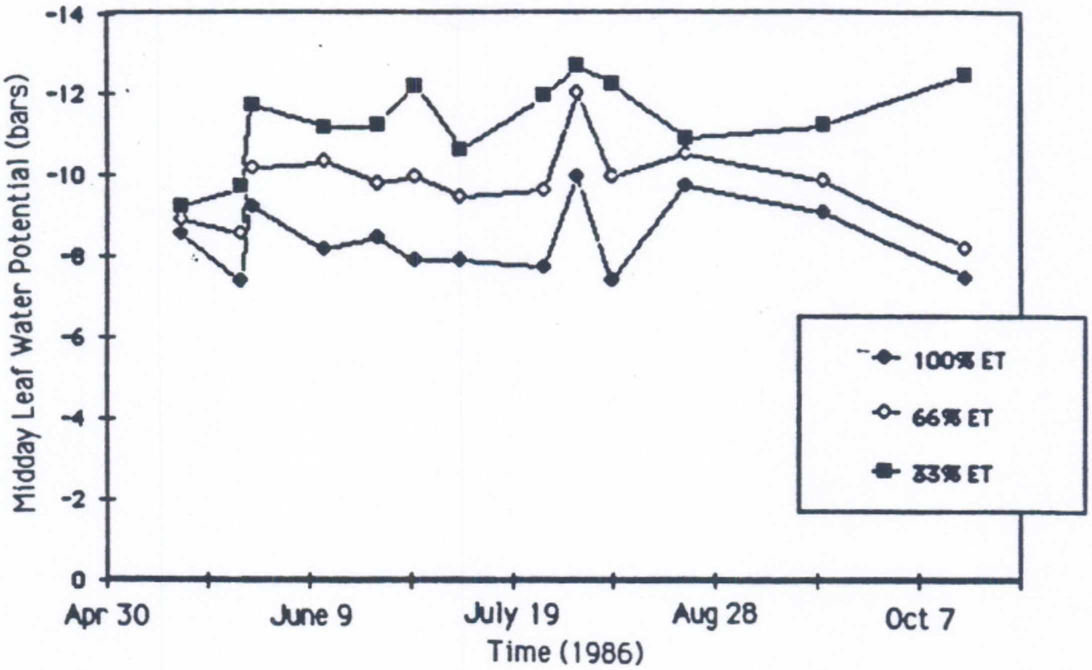

Figure 3. Midday leaf water potential of each high density irrigation treatment at weekly intervals.

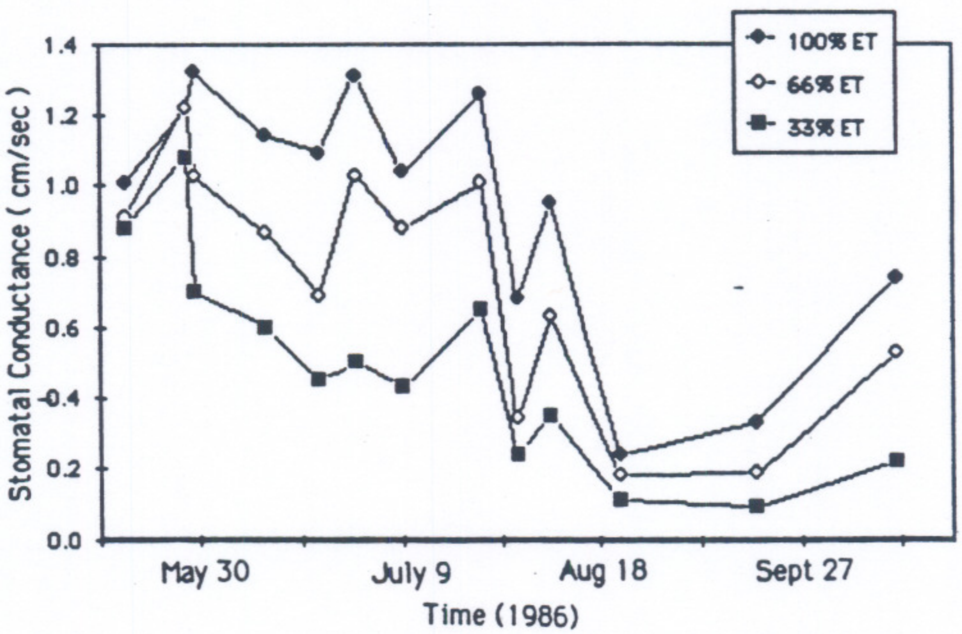

Figure 4. Stomatal conductance at midday of each high density irrigation treatment at weekly intervals.

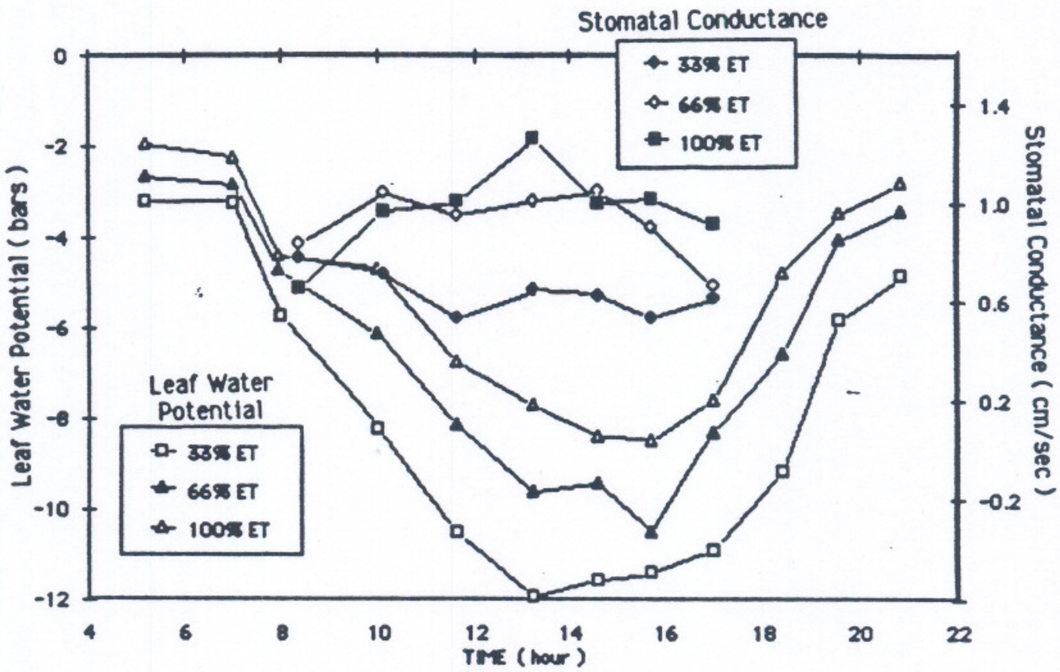

Figure 5. Leaf water potential and stomatal conductance for each high density irrigation treatment over a diurnal period on July 25, 1986.

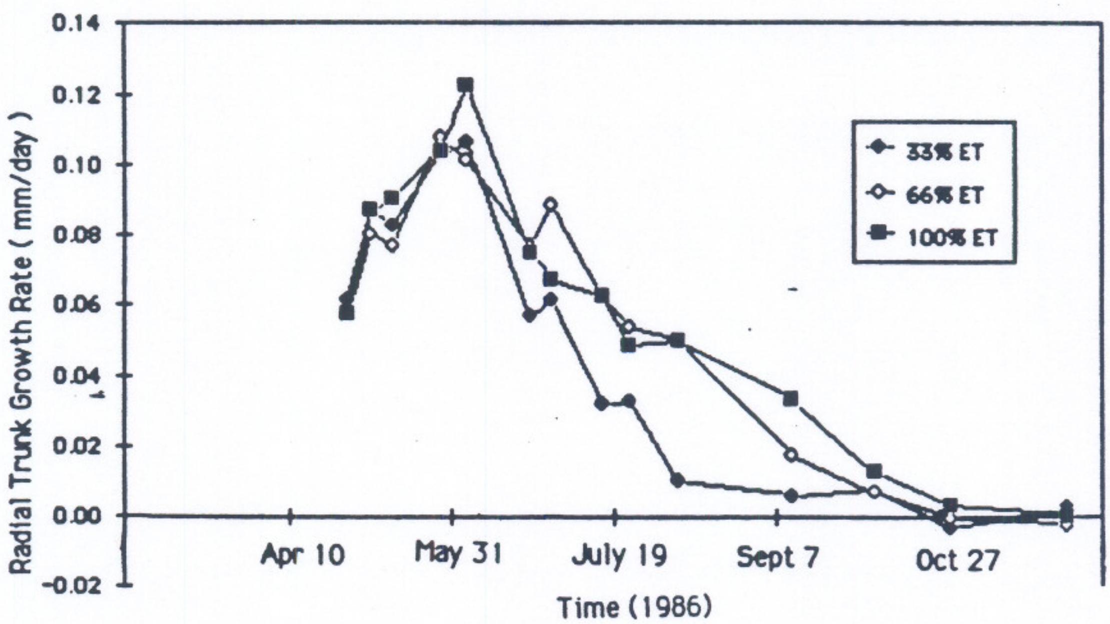

Figure 6. Radial trunk growth rates for each high density irrigation treatment in 1986.

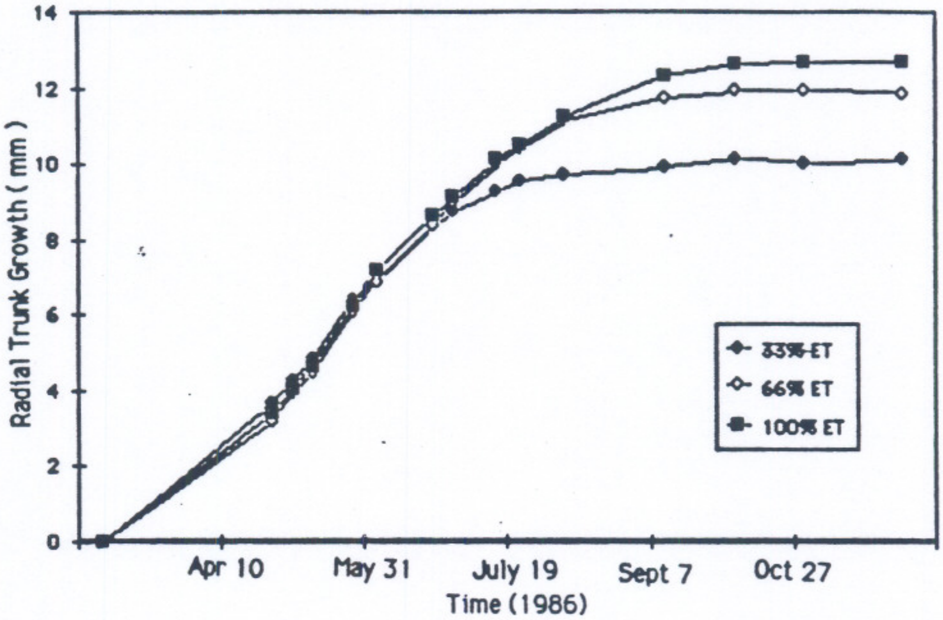

Figure 7. Cumulative radial trunk growth for each high density irrigation treatment beginning on February 28, 1986.