

Third Year Effects of Deficit Irrigation on Walnut Tree Performance

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ABSTRACT

The response of hedgerow cv. Chico walnuts to irrigation rates of 100, 66, and 33% of full ET_c (orchard water use) was evaluated for a third consecutive year in 1988. Both predawn and midday measurements of leaf water potential reflected the imposed plant water stress, although predawn and evening values showed the greatest separation between irrigation regimes. Seasonal midday and diurnal patterns of stomatal behavior suggested large reductions in carbon assimilation under deficit irrigation.

Yields of dry, in-shell nuts were 2.04, 1.34 and 1.01 tons/acre at 100, 66 and 33% ET_c , respectively. Yield differences were primarily due to differences in fruit load (961, 682, and 554 nuts/tree for the descending irrigation levels) and to a lesser extent, individual nut weight (9.87, 9.10, and 8.46 gm/nut for the descending irrigation levels). The relatively large average nut size under deficit irrigation was due to a compensatory effect of nut load on nut development. Harvest index values were 5.03, 5.14, and 4.53 nuts per ft^2 of shaded orchard floor area for the 100, 66, and 33% ET_c regimes, respectively. The reduced harvest index under the most severe water deprivation is the first instance recorded in this study of water stress impacting fruiting density. In previous seasons, even though yields have varied, harvest index values have been similar. We conclude that yield differences were due primarily to water stress-related reduced vegetative growth resulting in fewer fruiting positions per tree.

OBJECTIVES

The goal of this third year of our ongoing study of walnut water relations on cv. Chico is to establish the relationships between different levels of orchard water use (ET_c) and tree productivity.

This deficit irrigation part of the project began in 1986 and this report contains the results of the third stress year. The influence of irrigation-related nut temperature on the kernel quality of cv. Ashley is reported separately.

PROCEDURE

Three irrigation rates (33%, 66%, and 100% of full ET_c) were applied throughout the season to seventh year high density (11 x 22 ft) Chico walnut trees which comprise half of a 2.5 acre orchard at the Kearney Agricultural Center. The other section is conventionally-spaced (22 x 22 ft) trees that

are being irrigated at 100% ET_c and compared with similarly irrigated hedgerow trees. The results from this comparison will not be covered in this report. ET_c was estimated from previously determined crop coefficients and grass reference crop ET . The irrigation regimes are replicated three times in a randomized design. Each replication consists of 4 x 6 trees; the outside trees in each direction being guards resulting in eight monitored trees per plot.

Water is applied using circular pattern low volume sprinklers positioned in the tree rows 5.5 ft from each tree. The various irrigation regimes are accomplished by using different size sprinkler heads and water applied to each plot is measured with water meters. All plots are irrigated with the same frequency; generally two to four times per week. Applied water amounts are presented in Table 4.

Tree response to the deficit irrigation was monitored weekly with predawn and midday leaf measurements of water potential (pressure chamber) and midday stomatal conductance (steady state porometer). 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 May 26, July 1, August 4, and September 1, diurnal measurements of leaf water potential, stomatal conductance, and canopy temperature were taken.

Radial trunk growth was measured monthly during the season on eight trees per replication with a microdendrometer. Canopy size was assessed after development was complete by determining the shaded area of the orchard floor at 1:00 p.m. in late July. Measurements were made by counting the shaded squares of a grid drawn on a tarp and placed beneath the trees. Nut samples (24 per replication) were collected twice weekly and dried to determine the rate of dry weight accumulation. To assess vegetative growth, pruning weights were taken after a light summer (May) hand pruning and following mechanical hedging of the west side of tree rows in December.

The orchard was harvested on September 20 with a commercial shaker and individual tree field weights determined. Nut subsamples were collected (200 nuts per replication) and removed to the laboratory where the nut component weights (shell and kernel) and nut size (width and length) were evaluated. Additional subsamples were analyzed commercially by Diamond Walnut Growers, Inc. for nut size (5-category breakdown) and nut quality (6-category breakdown).

RESULTS AND DISCUSSION

Seasonal plant water status and stomatal behavior

Predawn leaf water potential over the season generally ranged from -1 to -2 bars for the 100% ET_c trees, -2 to -3 for 66% ET_c , and -2.5 to -4 for 33% ET_c . Lower available soil water levels are reflected by the lower values found in the deficit irrigated trees. Predawn leaf water potential is a commonly used indicator of plant water status and is considered by many to be the measurement most reflective of plant water stress.

Midday leaf water potentials taken over the season are shown in Figure 1. Distinct separation exists between the irrigation regimes. Much of the non-linearity of the data is due to variation in day-to-day evaporative demand and to a lesser extent, fluctuations in soil water levels. However, the data show that midday leaf water potential, at least on a relative basis, does reflect plant water stress in walnuts and as such, should not be discarded for possible use in applied water management.

Midday stomatal conductance showed a moderate decrease with time over the season for all irrigation regimes (Fig. 2). However, the rate of decrease was less than that observed in earlier seasons. Distinct separations occurred throughout the year between irrigation treatments, with the 100% ET_c trees averaging approximately 0.75 cm/sec, the 66% ET_c trees at 0.35 cm/sec, and the 33% ET_c treatment at 0.25 cm/sec. Since stomatal conductance is directly related to both transpiration and carbon assimilation, its magnitude is a useful indicator of the influence of deficit irrigation on these important plant processes.

Diurnal plant-based measurements

Due to the dynamic nature of stomatal activity, stomatal conductance measured with time over a single day provides information better suited to estimate the impact of water deprivation on time-averaged carbon assimilation. Diurnal measurements made on July 1 (a particularly hot day) of stomatal conductance, leaf water potential, and leaf temperature are shown in Figures 3-5. Again, distinct separations are evident between treatments throughout the day. At 100% ET_c, a maximum of 0.8 cm/sec was reached at 10:00 a.m. followed by a relatively steep decline to 0.35 cm/sec at 5:45 p.m. The 66% ET_c trees also had maximum stomatal conductance in the early morning (0.6 cm/sec) followed by rapid decline. At 33% ET_c, the maximum early morning stomatal conductance was 0.35 cm/sec with a subsequent decline to 0.20 cm/sec at 11:30 a.m. This value was maintained for the remainder of the day.

Diurnal measurements of leaf water potential also showed general separation over the day (Fig. 4). However, the most clear differences occurred during the times of least evaporative demand; the earliest (4:45 a.m.) and the latest (8:45 p.m.) measurements. Midday values illustrate the effect of the interactive nature of stomatal conductance, evaporative demand, and leaf water potential.

Canopy temperature measurements made with a ground-held infrared thermometer had good separation over the day (Fig. 5). Higher leaf temperatures in the deficit irrigation regimes are due to reduced evaporative cooling. It's clear that this type of measurement can clearly identify when relative transpiration rates are reduced. However, it should be pointed out that transpiration reduction (and thus, elevated canopy temperature) due to partial stomatal closure occurs only after moderate plant water stress levels are attained. Normally, this level of stress should not be allowed to develop unless plant performance is improved (or at least not diminished) by decreased vegetative growth. Cotton and seed alfalfa are examples where maximum vegetative growth is not desirable at certain growth stages, and thus may be suited for the use of canopy temperature measurements in applied water management. With deciduous trees, we normally irrigate to avoid any

decrease in transpiration, with the exception of regulated deficit irrigation during the lag phase of fruit growth now being tested and possibly postharvest. Thus, canopy temperature measurements with deciduous trees under conventional irrigation management can be used primarily to assess whether the trees are stressed, and thus is an evaluative rather than predictive tool.

Trunk growth and nut development

Seasonal radial trunk growth is shown in Fig. 6. Growth rates peaked in mid June, early June, and mid May for the 100, 66, and 33% ET_c levels, respectively.

Dry matter accumulation in the nuts is shown in Fig. 7 with the slope of the curves indicating the rate of growth. Rapid growth occurred from late May through early July at all irrigation levels, with virtually no differences observed in nut (hull, shell, and kernel) dry weight between treatments during this time period. Only later in the season when growth rates were lower did the relatively small differences in nut weight appear.

Walnut hydration levels with time showed distinct separation between irrigation levels, especially later in the season (Fig. 8). Hydration was directly related to the magnitude of the deficit irrigation.

Nut yield and quality

Harvest and other performance parameters are shown in Tables 1-4. Yields of dry, in-shell nuts were reduced more by the deficit irrigation than in the previous two seasons. For example, the 33% ET_c irrigation regime yield was reduced by 50% compared with the 100% ET_c treatment (1.01 vs. 2.04 tons/acre, respectively). Last season, the same comparison showed a reduction of 32% (2.61 vs. 3.78 tons/acre, respectively). The relatively large differences in yield due to the deficit irrigation were due primarily to a reduction in the fruit nut load per tree (Table 1), and to a lesser extent, reduced nut weight (Table 2). However, it's interesting to note that last year, when the fruit load differences between treatments were less, that differences in nut weights were greater. For example, the ratio of 33 to 100% ET_c dry nut weight was 79.2% last year compared with 85.7% this season. We believe this is due to a compensatory effect of nut load on fruit dry matter accumulation. In other words, the fact that the number of nuts per tree was significantly reduced this year in the 33 and 66% ET_c by three years of sustained deficit irrigation resulted in relatively greater nut growth.

The effects of plant water stress on vegetative growth are evident by the reduced canopy size (shaded area of the orchard floor) and pruning weights found in the deficit irrigation treatments (Table 1). Harvest index values (nut number and weight per unit shaded area) were similar for the 100 and 66% ET_c regimes and modestly lower at 33% ET_c . This reduction at the most severe deficit irrigation level is the only instance of decreased harvest index we have observed in three years. It suggests that carryover effects of previous years' severe stress are required to change the fruiting density of walnut. However, it's clear that the primary reason that water stress reduced marketable yield in our study was a reduction in vegetative growth and, therefore, fruiting positions.

Table 1. Harvest, fruiting density, and canopy growth-related data.

Treatment	Yield dry in-shell ¹		Fruit load (nuts/tree)	Shaded area ² (ft ²)	Harvest indexes ³			Pruning weights ³		
	(lbs/tree)	(tons/acre)			(nut/ft ²)	(lbs/ft ²)	(lbs lg.so./ft ²)	May	Dec	Total
100% ET _C	22.7	2.04	961	191.2	5.03	0.12	0.069	1.18	9.43	10.61
66% ET _C	14.9	1.34	682	132.6	5.14	0.11	0.047	0.87	5.19	6.06
33% ET _C	11.2	1.01	554	122.2	4.53	0.09	0.046	0.23	2.20	2.43

¹ 8% water content by weight

² measured on July 29

³ lg.so. = large sound nuts

⁴ fresh weights

Table 2. Nut component weights, sizes, kernel percentages, and commercial size classifications.

Treatment	Nut component weights			% Kernel	Nut dimensions			Nut size classification				
	Shell ----- (gm/nut)	Kernel (gm/nut)	Total -----		Length ----- (in)	Width (in)	Length/Width	Jumbo -----	Large -----	Medium -----	Baby -----	Peewee -----
100% ET _C	5.04	4.83	9.87	48.9	1.38	1.22	1.14	30.4	22.7	19.2	26.5	1.1
66% ET _C	4.60	4.50	9.10	49.5	1.33	1.20	1.11	17.5	20.3	28.1	33.4	0.7
33% ET _C	4.24	4.22	8.46	49.9	1.30	1.19	1.09	27.5	19.3	19.1	34.0	0.3

Table 2 presents data on kernel percentage and commercial nut size classification. Kernel percentage was slightly greater with increasing deficit irrigation severity, which conflicts with previous seasons' observations.

Nut length and size differences (Table 2) are consistent with the differences reported for the nut weights (Table 1). Note that the length to width ratio tends to decrease with increasing stress. In other words, plant water stress tends to give a smaller, somewhat fatter nut. Commercial nut sizes generally reflect the reduction in nut size due to the deficit irrigation, although a relatively large percentage of the 33% ET_c nut load was sized as Jumbo.

The production of large sound nuts was reduced by the deficit irrigation, as was edible yield but to a lesser extent (Table 3). Off-grade (predominantly mold), internal damage (mold), and insect damage (navel orange worm) all increased with increasing deficit irrigation severity. The RLI was modestly higher in the deficit irrigated kernels, indicating once again that cv. Chico is quite tolerant of heat-related injury.

Table 3. Commerical harvest quality parameters.

<u>Treatment</u>	<u>Edible Yield¹</u> -----% by weight-----	<u>Large Sound²</u>	<u>Off- Grade²</u>	<u>Internal Damage³</u> -----% by number----	<u>Insect Damage⁴</u>	<u>"New" RLI⁵</u>
100% ET _c	43.8	57.6	4.7	5.4	0.2	31.0
66% ET _c	41.8	41.9	10.7	11.0	1.2	31.9
33% ET _c	41.2	49.8	12.7	10.8	2.0	31.9

¹ Sample is dry in-shell

² Sample is dry kernel

³ Sample is large external sound

⁴ Total sample

⁵ Reflective light index. The higher the RLI, the lighter the kernel color.

Water use efficiency

Applied water use efficiency (WUE) values in terms of product produced per unit of water added are shown in Table 4. For dry in-shell, edible kernel, and large sound nuts, maximum WUE was achieved with the 33% ET_c regime. This is due to the following: 1) the most severe deficit irrigation regime resulted in better utilization of native soil water supplied from rainfall or carryover from the previous season, and 2) partitioning of carbohydrates favoring reproductive organs (the nuts) can be expected under plant water stress. The fact that the bulk of reproductive growth occurs prior to mid June, avoiding the high evaporative demand time of the year, encourages greater WUE for deficit irrigated trees.

Table 4. Water use efficiency expressed on a weight per unit amount of applied water for these product components.

<u>Treatment</u>	<u>Applied water</u> (acre-in/acre)	<u>Applied water use efficiency</u>		
		<u>Dry in-shell</u> -----	<u>Edible kernel</u> (lbs/acre-in) -----	<u>Large sound</u> -----
100% ET _c	40.4	101.1	44.3	58.3
66% ET _c	25.4	105.6	44.1	44.2
33% ET _c	15.5	130.1	53.6	64.8

CONCLUSIONS

The influence of deficit irrigation on nut yields is more severe in the third year of sustained stress than in the previous two seasons. Yield reductions were due primarily to reduced fruit loads and to a lesser extent, lower individual nut weight. The only slight reduction in nut size was due to a compensatory effect of fruit load on nut development. Harvest index values (nuts per unit shaded area of the orchard floor) were somewhat lower under the 33% ET_c regimes, indicating that severe water stress over a number of seasons is necessary to reduce fruiting density. Clearly, the biggest impact of water stress on marketable yields is due to reduced vegetative growth that results in fewer fruiting positions per tree.

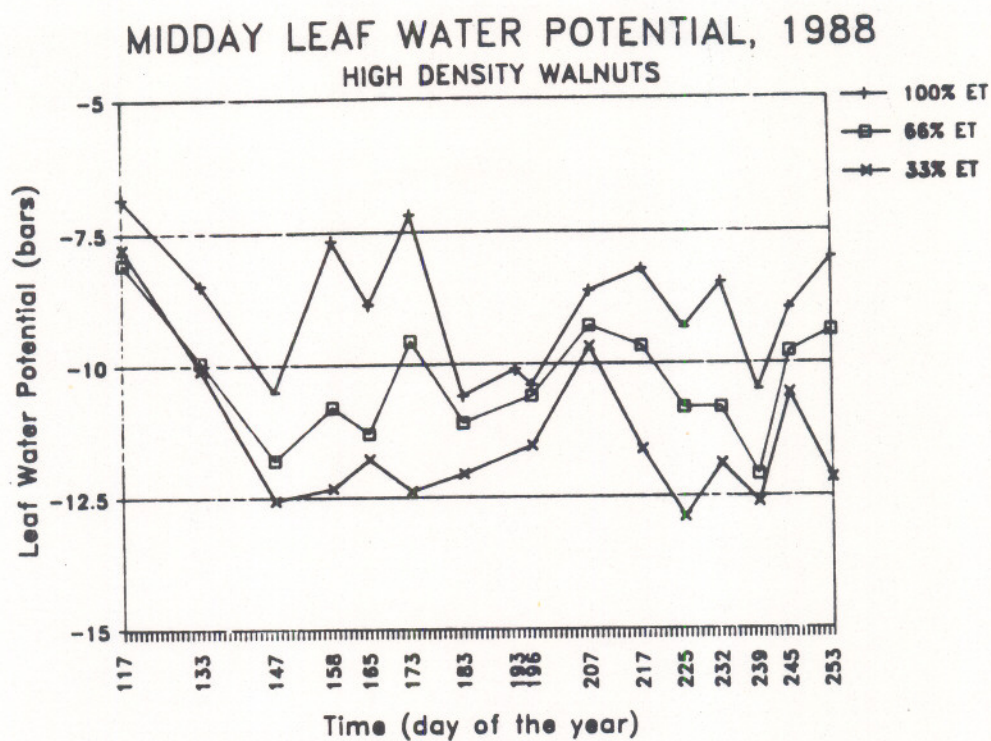


Figure 1. Midday leaf water potential over the season for the three ET_c regimes.

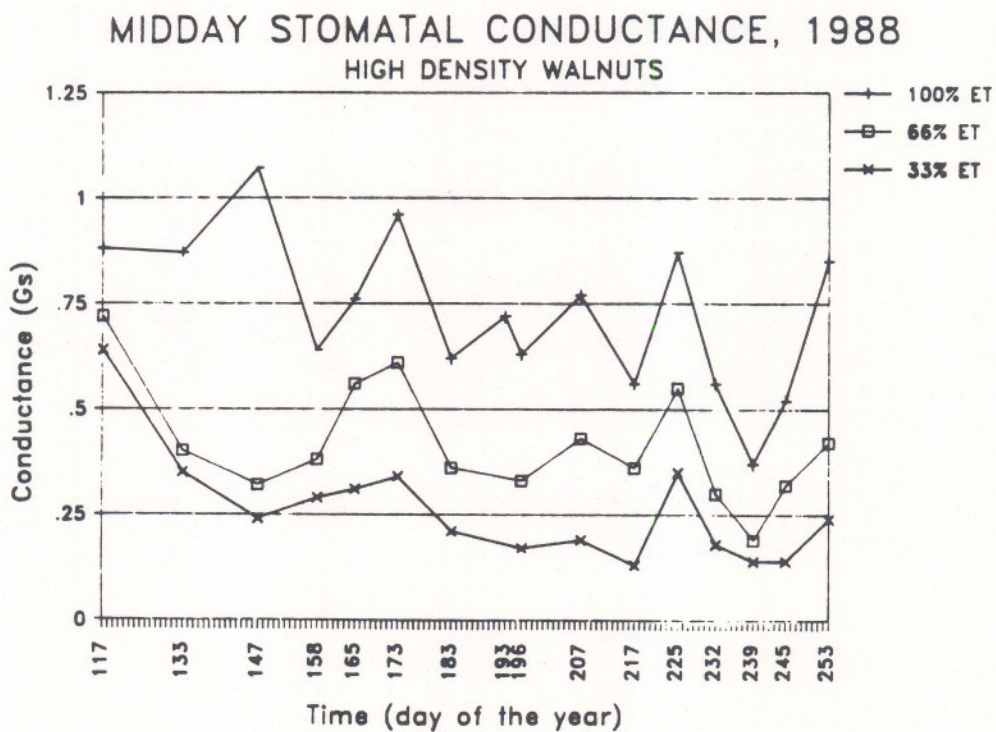


Figure 2. Midday stomatal conductance over the season.

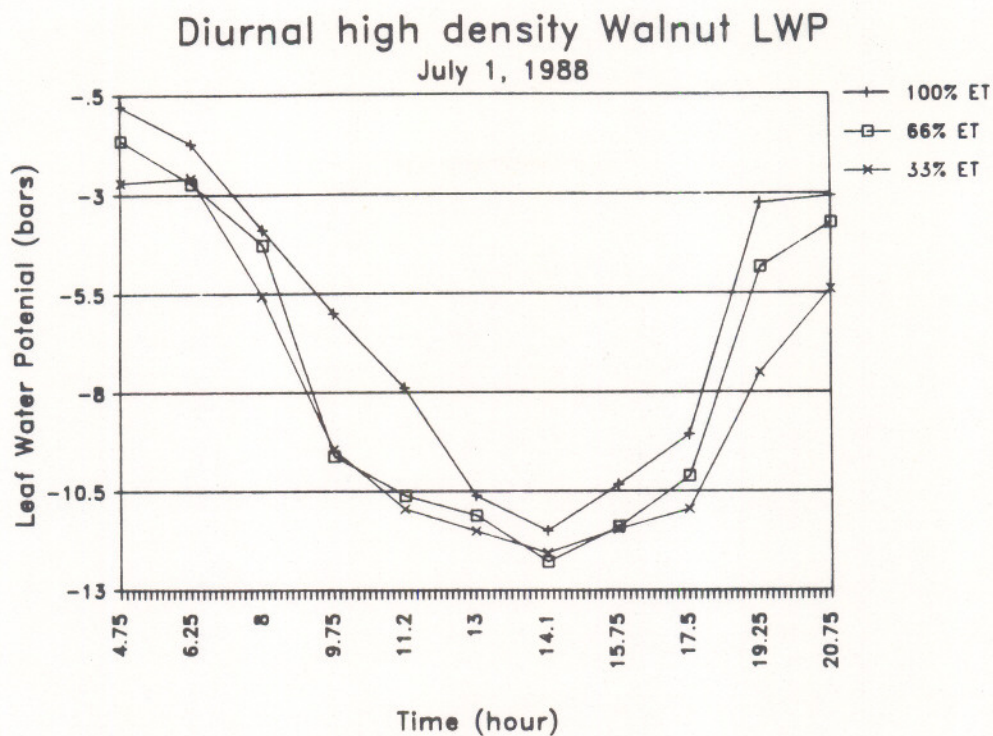


Figure 3. Diurnal measurements of leaf water potential taken on July 1, 1988; a relative high evaporative demand day.

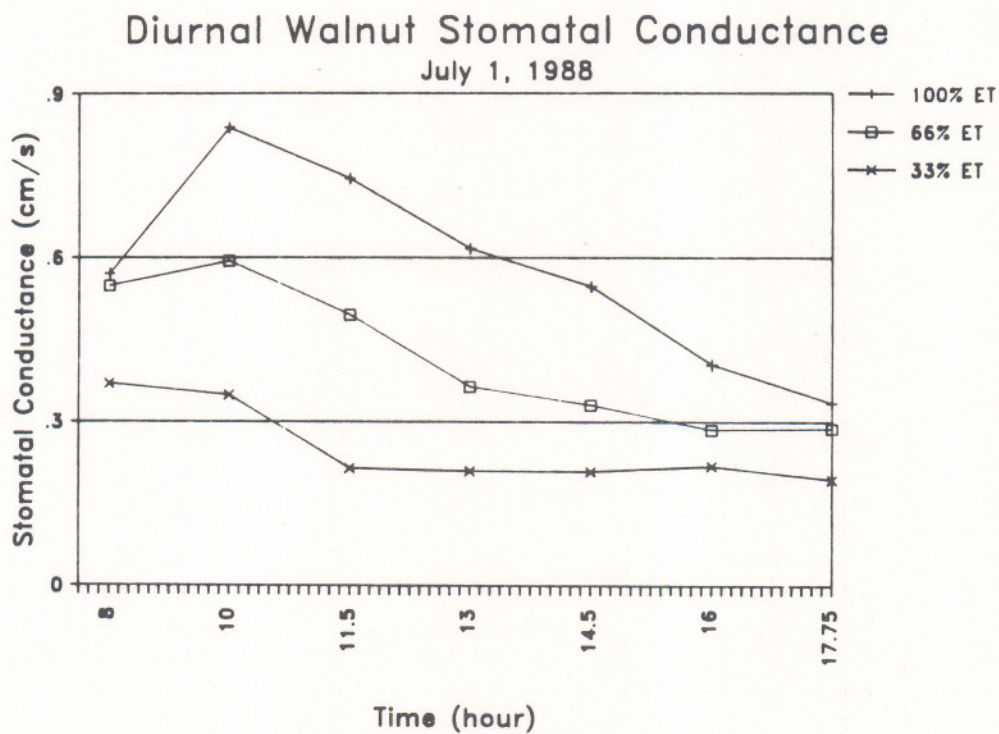


Figure 4. Diurnal stomatal conductance measurements taken on July 1.

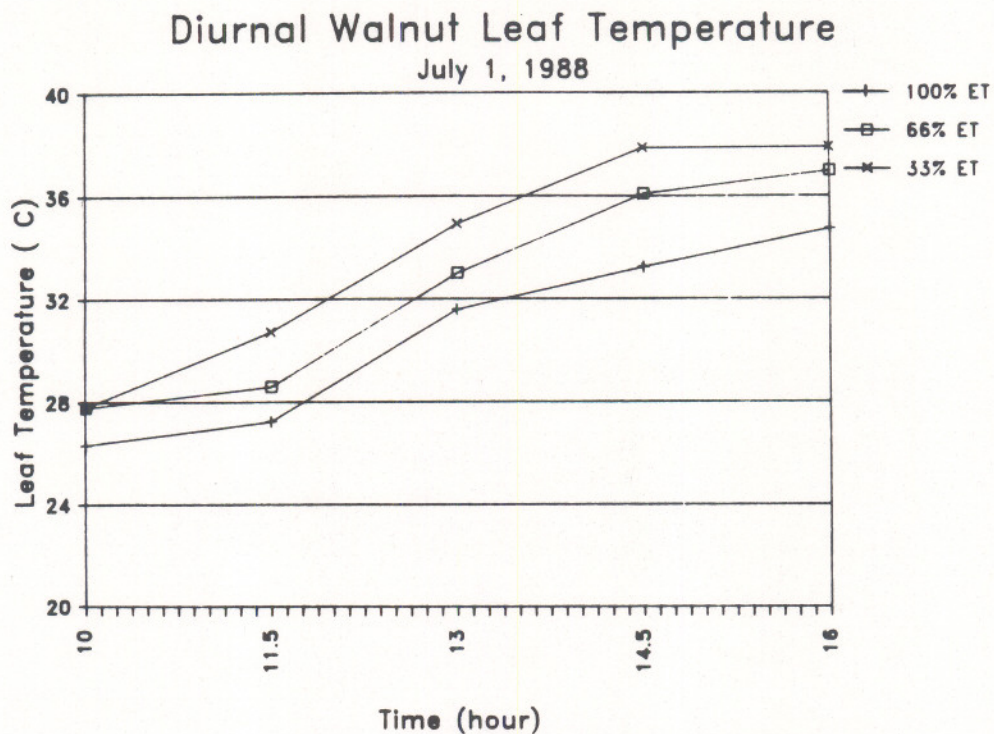


Figure 5. Diurnal canopy temperature measurements taken on July 1 with a ground-held infrared thermometer.

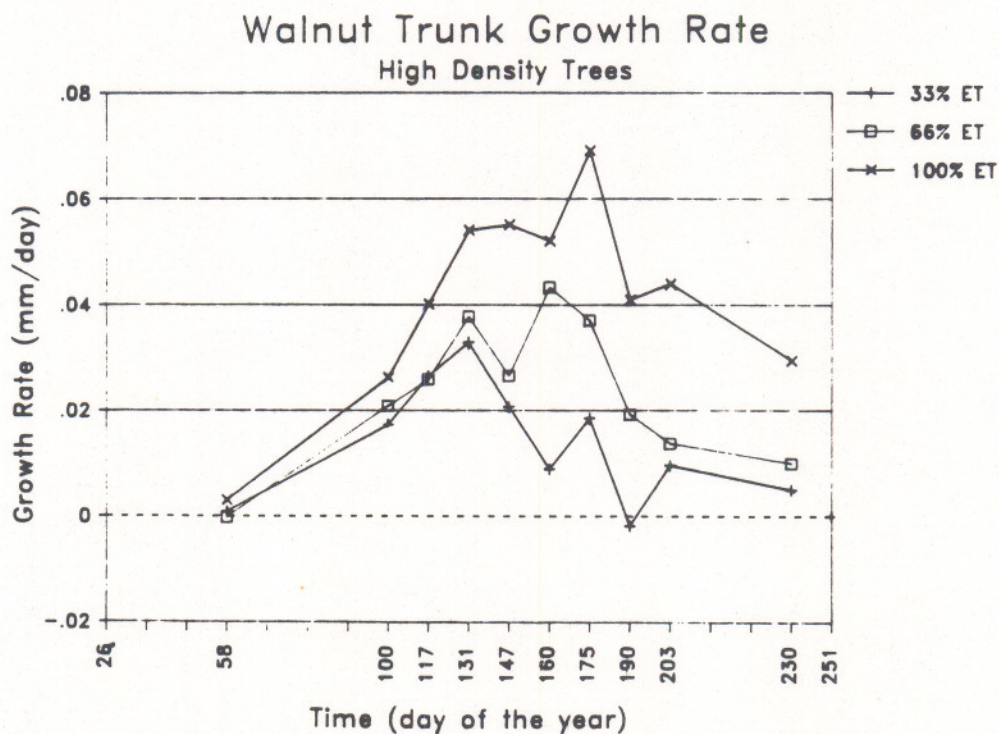


Figure 6. Radial trunk growth rate measurements over the season (day 160 is June 8).

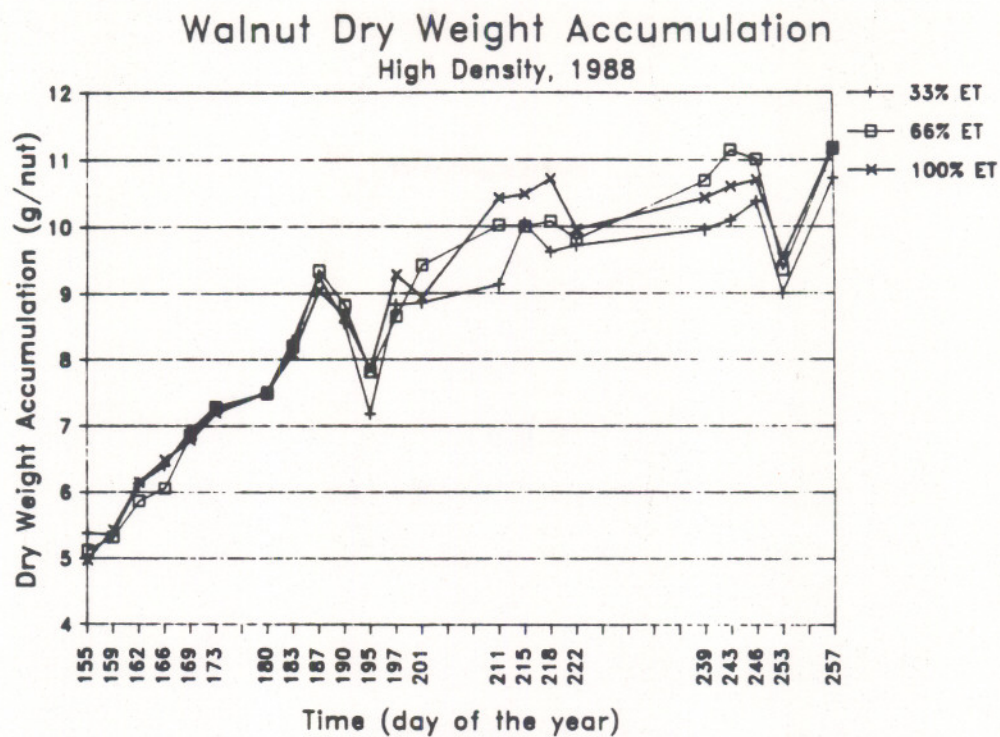


Figure 7. Dry weight accumulation in the nuts (hull, shell, and kernel) over the season.

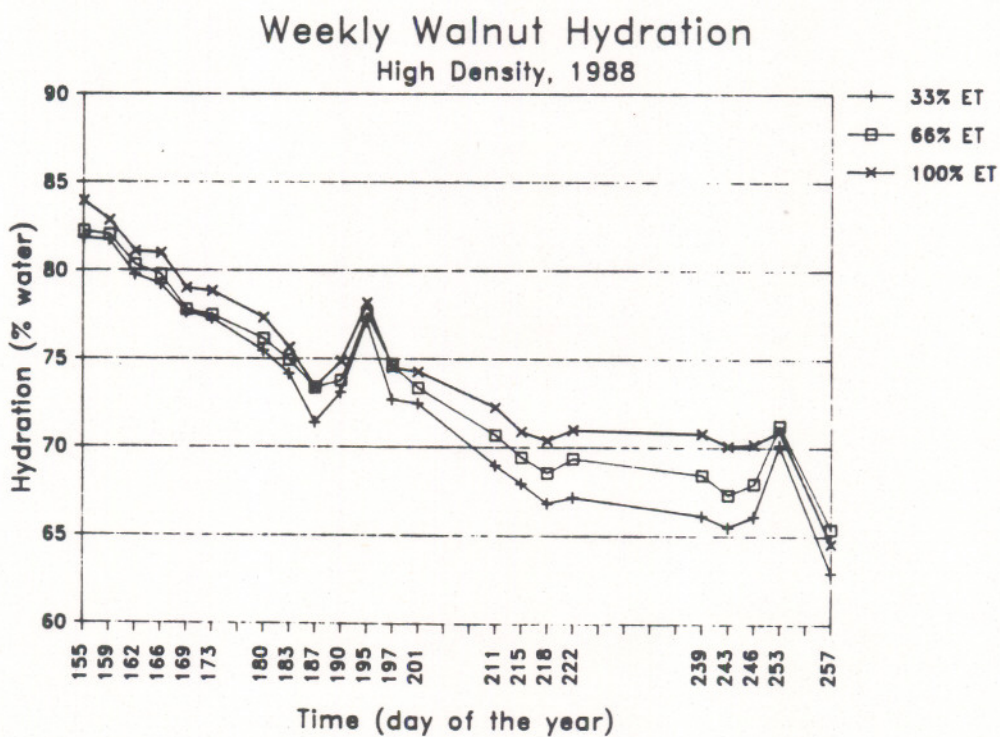


Figure 8. Nut hydration on a wet weight basis over the season.