Radial Trunk Growth of Almonds as Affected by Soil Water and Crop Density[1]

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Abstract. Radial trunk growth of mature almond trees under 4 irrigation treatments was measured with Verner dendrometers for 4 consecutive years. Trunk growth rates and total seasonal growth were affected primarily by soil water and secondarily by crop density conditions. In early spring, when soil water was abundant (near field capacity in entire root zone), the rate of trunk growth was inversely correlated with crop density. Later on, trunk growth was influenced more by soil moisture conditions. Irrigation early in the season increased trunk growth rates even though 30 to 40% available water remained throughout the root zone at time of irrigation. Irrigations after mid-season merely maintained the prevailing trunk growth rates.

Trunk growth of forest trees has been extensively studied (4, 5, 6). Such studies with fruit trees have been less adequate. Schroeder and Wieland (8) worked with avocado; Hilgeman (3) with citrus; Zeiger and Childers (12) and Taerum (9) with apple; and Verner et al. (11) with peach, prune, and apples.

Sensitive dendrometers (1, 7, 10) and dendrographs (2) have been used to detect changes in the size of tree trunks as affected by climatic conditions, levels of soil moisture, rainfall, high humidity and irrigations.

The present study was undertaken to determine the effect of soil water and crop density on trunk growth of mature almond trees utilizing the simple and inexpensive Verner dendrometer (10). The authors are unaware of any such studies carried on previously with almonds although they are frequently grown under conditions of limited water supply.

Materials and Methods

This study was begun in the spring of 1963 and continued for 4 seasons in a 20-year-old almond orchard growing in Yolo loam (deep alluvial soil) on the campus of the University of California at Davis. The orchard was under clean-cultivation culture with minimal annual pruning.

Verner-type dendrometers were installed, one instrument per tree, in 4 differentially irrigated rows of 10 trees each. Verner (11) suggested the use of 10 trees per plot. However, in this study, end trees were not instrumented, leaving 8 instrumented trees per row. Two guard rows separated the irrigation treatments.

To install the dendrometers, a well-rounded portion of the trunk was selected and a hole slightly larger than the diameter of the anchoring screw was bored through the bark and partly into the wood. The screw was firmly anchored in the wood beyond the bored hole, allowing the bark and outer xylem tissue to expand or contract without disturbing the position of the screw. The zinc template was glued onto a smoothed portion of the bark with an epoxy adhesive.

The Verner dendrometer always shows the maximum radius attained. As the trunk expands outward (generally at night until early morning), the lever of the dendrometer is pushed outward. When expansion stops, the lever remains stationary and is not retracted by any trunk shrinkage. If shrinkage occurs, a gap develops between the trunk and the lever. The fixed position of the lever represents the maximum expansion, and the gap the amount of shrinkage.

Readings were taken every 2 days between 4:00 and 6:00 PM when the trunk diameter reached its diurnal minimum, thus obtaining data on both maximum expansion and shrinkage. The data from trees in each treatment row were averaged. Studies on diurnal shrinkage as affected by soil water and evaporative conditions are being reported in a subsequent paper.

There were 4 irrigation treatments: A) irrigated every 2 weeks during the growing season (approximately 9 irrigations); B) irrigated when the water content, averaged over the top 4 feet of soil, was still about 3 percent above the wilting point, WP (4 irrigations); C) irrigated when the average soil water in the top 4 feet reached WP (2 irrigations); and D) no irrigation. For several years before 1963, trees in plots A, B, and C received 2 irrigations per year and those in plot D, none.

Irrigation water was applied in rectangular checks with 2 trees per check. The depth of water applied was calculated to return the soil to approximately field capacity throughout the root zone. Gravimetric samples were obtained in foot increments to 6 ft before each irrigation, and once per month in the unirrigated plot. Soil water percentages from the top 4 ft were averaged and plotted.

Yields per tree and nut sizes were determined at harvest in order to estimate the total number of nuts per tree. Trunk circumference was measured at the end of each year, trunk cross-sectional area calculated, and a crop density figure obtained (number of nuts per cm^2 of cross-sectional area of the trunk).

Results and Discussion

The alternate-bearing tendency of almonds was quite evident during the 4 years of this study (Table 1), with 1963 a moderately light crop year, 1964 heavy, 1965 very light, and 1966 again heavy. Also, preseason winter rainfall was above normal prior to the 1963 and 1965 seasons and below normal for 1964 and 1966. Thus, rainfall and crop conditions and subsequent trunk growth patterns were very similar in alternate years. Trunk growth curves for 1964 are therefore used to illustrate 1964 and 1966 results, and 1965 curves to illustrate 1963 and 1965.

1964. Rainfall in the winter and spring of 1963–64 was about 11 inches. This resulted in a relatively low reserve of soil water in the spring. In the dry plot (D) the soil was wet down to only 4 ft, and the soil below was at WP.

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Table 1. Crop density[a], total cumulative radial growth and preseason rainfall for the four-year study.

Treatment	No. of irrigations per treatment	1963 Crop density[a]	1963 Total radial growth to 10/16 (cm)	1964 Crop density[a]	1964 Total radial growth to 10/17 (cm)	1965 Crop density[a]	1965 Total radial growth to 10/5 (cm)	1966 Crop density[a]	1966 Total radial growth to 10/25 (cm)
A..........	9	7.9	.546	11.3	.704	4.2	.615	13.1	.470
B..........	4	4.1	.607	11.0	.627	3.5	.683	10.6	.330
C..........	2	8.5	.315	13.1	.305	3.1	.531	14.6	.155
D..........	0	7.5	.396	14.7	.152	1.6	.559	14.9	.076
LSD .05.....		2.1	.160	2.2	.124	1.0	.167	2.4	.117
Preseason rainfall (inches)		27.1		11.2		18.6		10.9	

[a]Crop density: number of nuts per cm² of trunk cross-sectional area.

The crop load was heavy, ranging from 11 to 15 nuts per cm^2 of trunk cross-sectional area. The average crop for this orchard is about 6 to 10 nuts per cm^2.

The total cumulative radial growth of the trunk at the end of the season (Fig. 1) was greatest in treatment A. Treatment B had slightly less growth even though the crop load was slightly less than A. Treatment C, with a higher crop density, had considerably less growth than A or B. Treatment D, with the highest crop density, had the least growth.

In the beginning of the season, treatments A and B, with practically the same crop density, were growing at about the same rate until A was irrigated in late April. Then the growth rate of A gradually exceeded that of B even though the soil water was well above WP in both treatments (Fig. 2). By the end of May, total growth in A was significantly greater than B. Also, at the end of May, the growth rate in B was higher than in C, although the soil water level at this time was the same in both treatments. Neither had been irrigated yet. The crop density in C, however, was higher than that of B. Since the soil water conditions were the same in both, it can be assumed that the growth rate was lower in C than in B because of the heavier crop. Likewise, the growth rate was the lowest in treatment D which had the highest crop density.

In June, growth was suddenly reduced in both C and D when soil water neared WP in both plots. Growth resumed in C when an irrigation was applied in late June, but it did not resume in D (not irrigated).

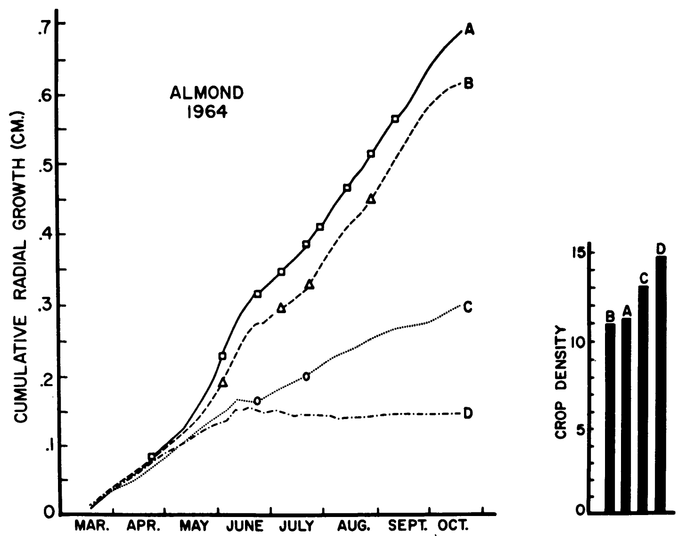

Fig. 1. Cumulative radial trunk growth (cm) and crop density (number of nuts per cm² of trunk cross-sectional area) for 1964. Treatment A had 9 irrigations during the season; treatment B, 4; C, 2; D, none. Symbols on curves indicate irrigation dates.

The first irrigation of the season in treatment A was

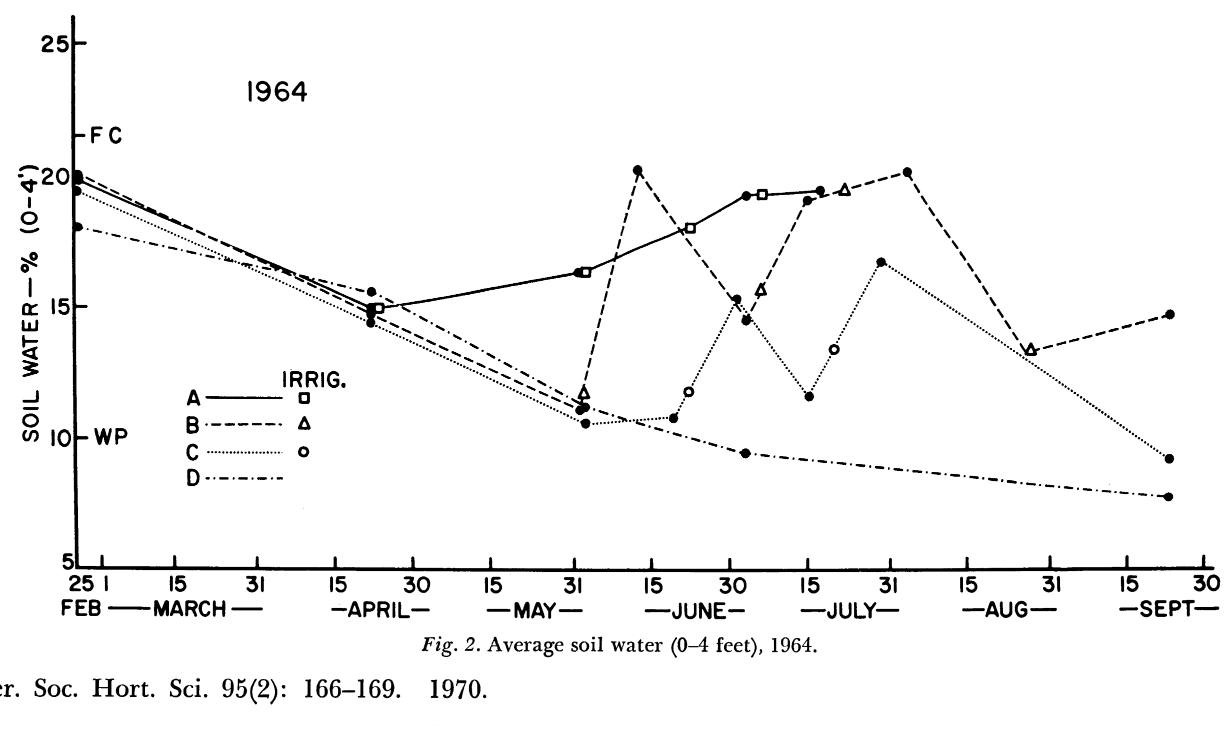

Fig. 2. Average soil water (0–4 feet), 1964.

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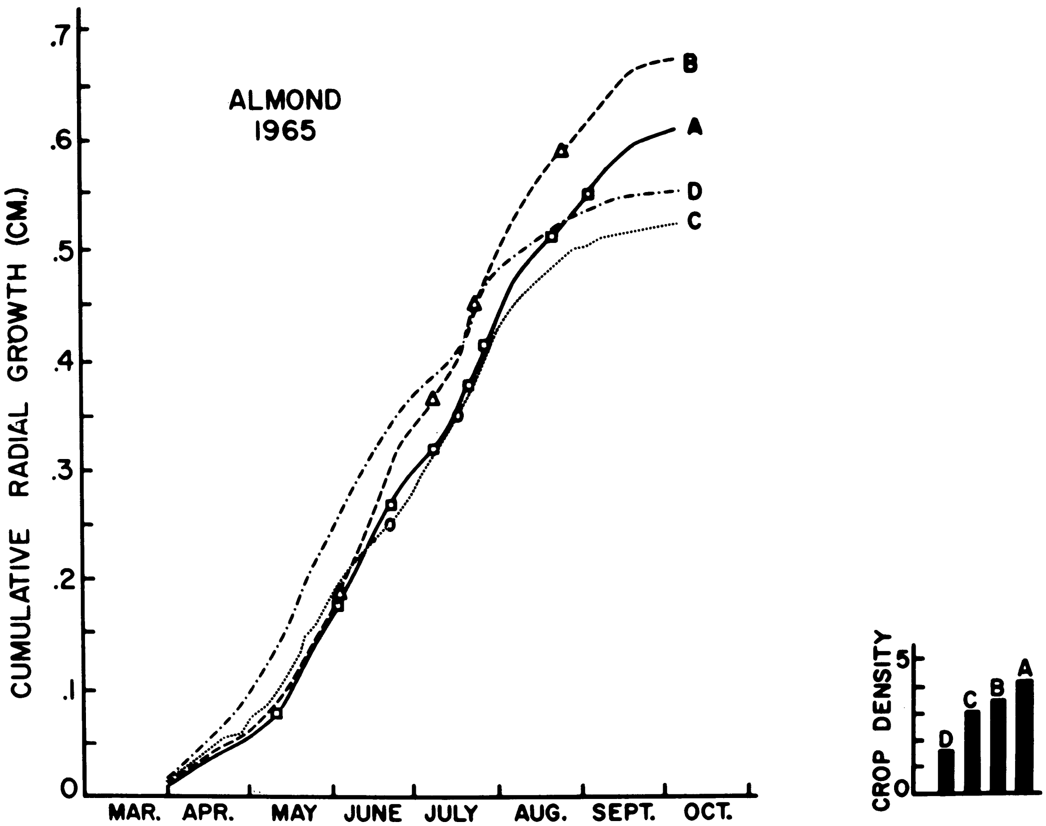

Fig. 3. Cumulative radial trunk growth (cm) and crop density (number of nuts per cm^2 of trunk cross-sectional area) for 1965. Treatment A had 9 irrigations during the season; treatment B, 4; C, 2; and D, none. Symbols on curves indicate irrigation dates.

followed by a growth response although at time of irrigation 30 to 40% available water still remained throughout the top 4 ft of soil. Irrigations later in the season did not further increase the rate of growth. Also, the rate of growth in A, from late June on, was no greater than B even though A was given twice as many irrigations as B. In C, the last irrigation (late July) did not bring about an increase in growth rate although soil water content was close to WP before irrigation.

1965. Unlike in 1964, the preseason rainfall in 1965 was approximately 19 inches. The normal average is about 16. Therefore, soil water was abundant down to 6 feet in all plots prior to spring growth. The crop was extremely light—only 2 to 4 nuts per cm^2 of trunk area.

With a very light crop and adequate soil water, trunk growth did not differ much between treatments until late in the season (Fig. 3). As treatments D and C approached WP in mid-July and late August, respectively, (Fig. 4)

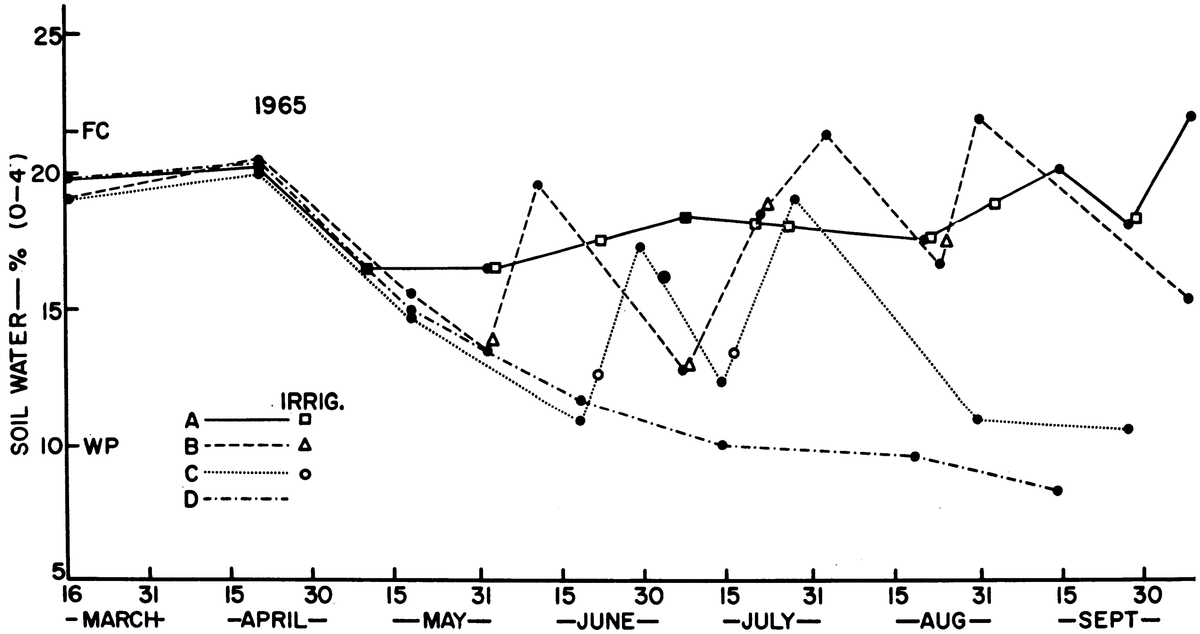

Fig. 4. Average soil water (0–4 feet), 1965.

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trunk growth rates were markedly reduced. Treatments A and B, in contrast, had sufficient irrigations so that growth was not restricted by soil water deficits.

Total growth in B was greater than in A although B had fewer irrigations. However, crop density was higher in A, indicating that the heavier crop suppressed trunk growth. Even in the water-deficient plots (C and D), the plot with the lower crop density (D) had the greater total trunk growth. Also in the early part of the season, when all plots had abundant soil water, trunk growth rates up to the time of the first irrigation were correlated inversely with crop density ($r = -0.992$). Growth rates decreased in order from treatments D to A, the order in which the crop loads increased.

After irrigations were started, however, this order was not maintained. Thus, treatment A, whose early growth was the slowest (because of the largest crop density), by mid-June (after 2 irrigations) was growing as fast as the unirrigated treatment D, which had initially been growing twice as rapidly. Later, as the soil water content in D decreased and approached WP, growth in D slowed while A maintained its rate. A temporary increase in growth rate of D in late July was associated with a period of unseasonally cool weather which diminished the effect of soil water deficit on the water balance in the tree. However, with the return of higher temperatures the growth rate was again markedly reduced.

In each of the 4 years of the study, both the soil water supply and crop load influenced rate of trunk growth and total seasonal growth.

Trunk growth was primarily influenced by soil water and secondarily by crop load. This was apparent in the low-rainfall years of 1964 and 1966, during which C and D reached WP in mid-season. Trunk growth was stopped and resumed only after irrigation of treatment C in late June. Even then growth in C never equaled the rate in plots A and B which were irrigated much earlier in the season. This indicates that irrigations late in mid-season have much less effect on current rates of trunk growth than early irrigations.

In all 4 years early irrigations (early May and June) increased trunk growth rate in treatments A and B, even though the average soil water content throughout the top 4 ft of soil was well above WP (30 to 40% available water remained) at time of irrigation. Later irrigations in A and B, whether at intervals of 2 or 4 weeks, did not increase growth rate further but merely maintained the rate established earlier.

The beneficial effect of irrigating early was greater in years of high crop density. Even in high-crop years, irrigation had more influence on final trunk size than did crop load. Although these studies indicate that soil water conditions are a primary factor in determining seasonal trunk growth, differences in crop density, even during light crop years, will influence trunk growth when soil water is not limiting.

This study indicates that high crop density in almonds increases the need for irrigation, especially early in the season. During years of a low crop density, normal trunk growth rates may be maintained with a schedule of less frequent irrigations.

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