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Physiological and Growth Responses of Mature Peach Trees to Postharvest Water Stress

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Abstract. **Peach trees (*Prunus persica* L. Batsch cv. Regina) were subjected to three levels of postharvest irrigation between 15 June and 15 Oct. 1983. Wet-treatment (control) trees were irrigated at 3-week intervals, medium-treatment trees received one, and dry-treatment trees received no postharvest irrigations. Significant differences in seasonal patterns of stomatal conductance were found among all treatments, with conductance varying in proportion to irrigation level. Wet-treatment pre-dawn water potential (ψ_w) remained nearly constant at -0.3 MPa throughout the postharvest season, whereas the dry-treatment readings became more negative as the season progressed. Differences in mid-day ψ_w were less distinct, but generally reflected pre-dawn water status. The seasonal increase in trunk radius of the dry-treatment trees was reduced by 33% relative to either wet or medium treatments. The amount of daily trunk radial shrinkage was inversely proportional to irrigation level. Dormant pruning weights were 13% less in dry treatments than wet treatments. Return bloom of dry-treatment trees in Spring 1984 was 30% and 40% greater than medium- and wet-treatment return bloom, respectively. Dry-treatment fruit set was 70% greater than medium- or wet-treatment fruit set. Following fruit thinning, there were no significant differences among treatments for fruit yield or fruit size, but fruit maturity was slightly delayed in the dry treatment.**

The San Joaquin and Sacramento Valleys are major stone fruit production areas in California. These regions are characterized by good soils, high summer temperatures, high evaporation rates, but little or no summer rainfall. Consequently, high orchard productivity is highly dependent on adequate irrigation. There is an increasing demand on water resources used for irrigation and a need to maximize agricultural water use efficiency. Chalmers et al. (7, 8) suggested that excessive peach tree growth can be controlled by regulated deficit irrigation during stages I and II of fruit growth in late-maturing peach and pear cultivars. In California, there are numerous early maturing stone fruit cultivars that ripen before 1 July and have truncated stage II phases of fruit growth, for which such a strategy is not feasible. However, these cultivars may be suitable for using a postharvest water deficit to accomplish similar goals.

Although it is generally recognized that the postharvest water requirements are less than preharvest requirements, quantitative observations of tree postharvest water relations are limited and have emphasized the potential negative effects of postharvest water stress. Research by Hendrickson and Veihmeyer (12), Brown (3), and Uriu (18) indicates that postharvest water stress in apricots could have detrimental effects on flower bud development and subsequent fruiting. Postharvest water deficits with almond can have significant effects on the growth of young trees (6, 11). However, after much research on mid- or late-season irrigation of several tree crops, Veihmeyer (19) concluded that water deficits during this period had minimal effects on vegetative tree growth.

The goals of this study were to determine the physiological response of mature peach trees to water stress and investigate the possibilities of conserving water and controlling vegetative growth through reduced postharvest irrigation.

Materials and Methods

Site. The experiment was conducted in Summer 1983 in a 1.4-ha block of 8-year-old 'Regina' peach trees located at the Univ. of California Kearney Agricultural Center, Parlier. Tree spacing was 6.1 × 6.1 m. The orchard originally was planted as a rootstock evaluation trial and was developed under furrow irrigation. Thirty-six experimental trees, 12 on 'Nemaguard' rootstock, 12 on 'Nemared' rootstock, and 12 on 'Lovell' rootstock, were selected for most of the measurements taken.

The soil is a sandy loam of the Hanford series (typic xerothents), with ≈530 mm of available water in a 3-m soil profile. Average annual rainfall at the site is ≈250 mm, with virtually all rainfall occurring between November and April. No significant rainfall occurred during the 1983 growing season (April–October).

Treatments. All trees received normal irrigation during Spring 1983. The last uniform full-orchard irrigation was applied on 13 June, just prior to harvest, after which the entire orchard was divided into six treatment blocks. Each block consisted of two adjacent tree rows separated on both sides from other treatment blocks by two rows of nonexperimental guard trees. Within each of the six treatment blocks there were six randomly distributed experimental trees, two trees on each of the three rootstocks. Treatment blocks were randomly paired, and pairs then were subjected to one of three irrigation frequencies. Thus, for statistical considerations, there were three treatments with 12 trees per treatment, or four trees per rootstock per treatment.

Furrow irrigation treatments consisted of a wet, an intermediate, and a dry treatment. Wet-treatment trees were irrigated at 3-week intervals with ≈15 cm of water applied per irrigation. Five irrigations were applied in the course of the experiment, for a postharvest total of ≈75 cm. This amount represented the control treatment and approximated normal irrigation scheduling in San Joaquin Valley peach orchards.

Intermediate-treatment trees were irrigated at 8-week intervals, once in mid-August and again in mid-October. These trees received 23 cm of water in August and 15 in mid-October, for a total postharvest irrigation of ≈38 cm.

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Dry-treatment trees received no irrigation from 13 June until mid-October, when 15 cm was applied.

Prior to the 11 Aug., medium-treatment irrigation, medium- and dry-treatment physiological responses were not significantly different. Thus, before 11 Aug., the medium treatment was effectively a dry treatment, and appears as such in Figs. 1–5.

Prior to harvest in Spring 1984, all treatments were irrigated at 7- to 10-day intervals.

Measurements. Leaf conductance to water vapor (g_l), calculated as the inverse of leaf resistance, was monitored at weekly intervals from 14 July to 17 Sept. 1983 using a LI-1600 steady state porometer (model #LL-190S-1, LI-COR). Measurements were made between 0900 and 1100 HR Pacific Standard Time (PST), and 1300 and 1500 HR PST on three trees per treatment.

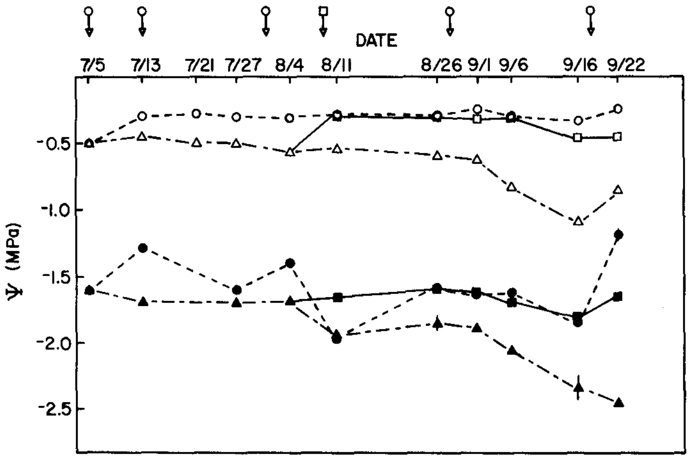

Fig. 1. Seasonal pre-dawn (open symbols) and mid-day (solid symbols) patterns of leaf water potential (ψ) in response to irrigation treatment. Circles = wet treatment; squares = medium treatment; triangles = dry treatment; arrows represent irrigations of appropriate treatments. Symbols represent means of three shoot tips on each of three trees per irrigation treatment ± SE. Where not shown, SE bars are within the area of the symbol.

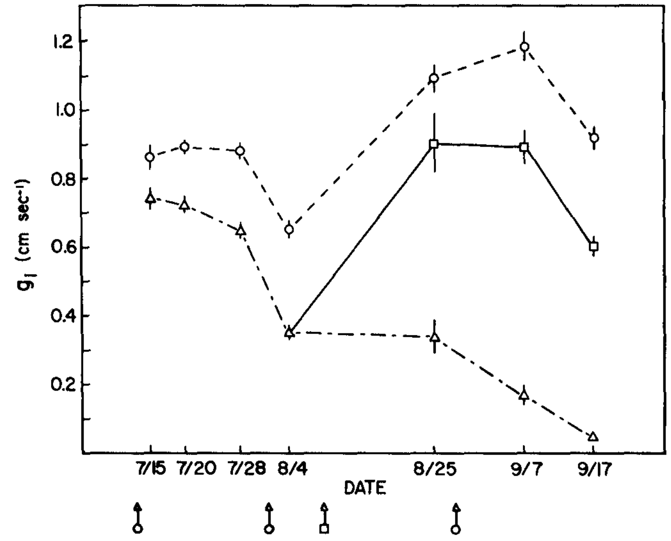

Fig. 2. Seasonal pattern of morning leaf conductance (g_l) in response to irrigation treatment. Circles = wet treatment; squares = medium treatment; triangles = dry treatment; arrows represent irrigations of appropriate treatments. Symbols represent means of five leaves on each of three trees per irrigation treatment ± SE. Where not shown, SE bars are within the area of the symbol.

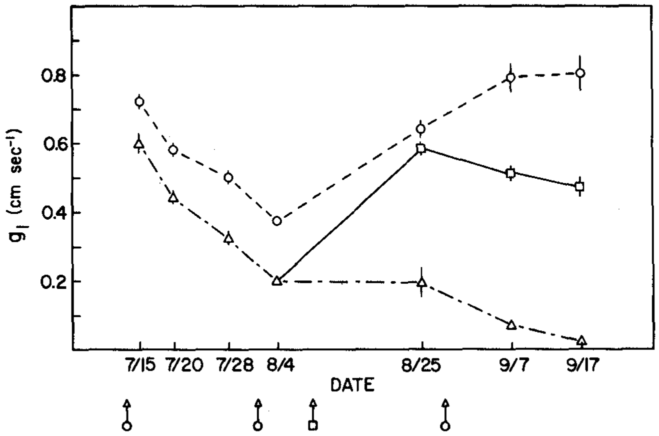

Fig. 3. Seasonal pattern of afternoon leaf conductance g_l in response to irrigation treatment. Circles = wet treatment; squares = medium treatment; triangles = dry treatment; arrows represent irrigations of appropriate treatments. Symbols represent means of five leaves on each of three trees per irrigation treatment ± SE. Where not shown, SE bars are within the area of the symbol.

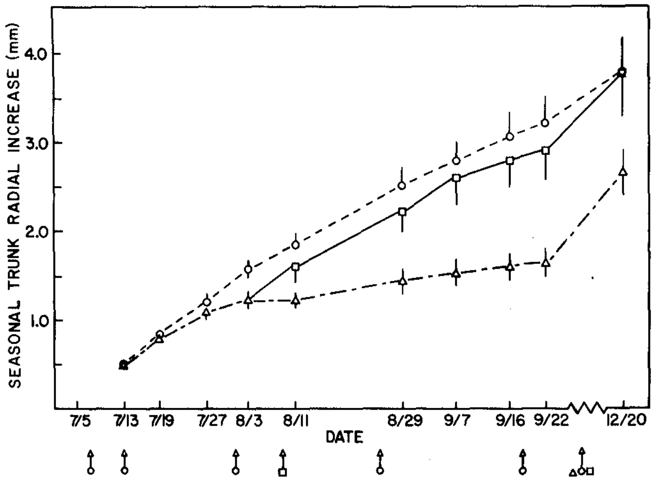

Fig. 4. Seasonal pattern of trunk radial growth in response to irrigation treatment. Circles = wet treatment; squares = medium treatment; triangles = dry treatment; arrows represent irrigation treatments. Symbols represent means of all 12 trees per irrigation treatment ± SE. Where not shown, SE bars are within the area of the symbols.

For each treatment, mean g_l was calculated from five individual, well-exposed leaves at the top of the canopy of each of the trees.

Shoot tip water potential was monitored weekly from 5 July to 22 Sept. 1983 using the pressure bomb technique of Scholander et al. (16). The short petioles of the peach leaves prevented the use of individual leaves in the pressure chamber; rather, shoot tips with two to four mature leaves each were excised and immediately (within 30 sec) subjected to pressure. Since this reading should be the average of the two to four mature leaves, it is referred to as leaf water potential (ψ_w) throughout. Readings were taken at pre-dawn and mid-day (1300–1500 HR PST) to obtain maximum and minimum ψ_w values. Measurements were made on at least three trees per irrigation treatment. For each tree monitored, mean ψ_w was calculated from three separate shoot tip readings. All shoot tips were taken from well-exposed shoots at the top of the tree canopy.

Shoot length was measured periodically on five randomly

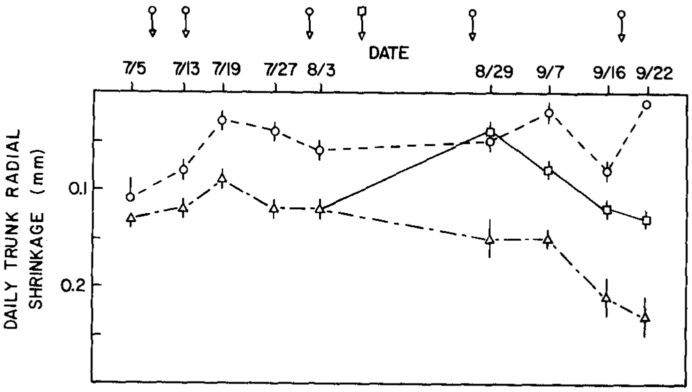

Fig. 5. Seasonal pattern of daily trunk radial shrinkage in response to irrigation treatment. Circles = wet treatment; squares = medium treatment; triangles = dry treatment; arrows represent irrigations of appropriate treatments. Symbols represent means of all 12 trees per irrigation treatment ± SE. Where not shown, SE bars are within the area of the symbols.

tagged, horizontal, secondary shoots in the top of each experimental tree. Shoots were tagged on 6 July 1983, and final shoot length was measured on 1 Sept. 1983.

In each of the 36 experimental trees, basal diameters of all vigorous (upright and branched), current-season shoots were measured on 18 Dec. 1983. Shoot diameters were measured 10 cm above the base of the shoot to avoid basal reaction wood.

Pruning weights (fresh weight) were determined for each tree on 19 Dec. 1983. Immediately following dormant-pruning, all prunings were gathered and weighed.

Trunk radial shrinkage and swelling was monitored on all 36 trees at weekly intervals from 5 July to 22 Sept. 1983 using a microdendrometer (A.B. Pulco, Manufacturer, Lund, Sweden). Readings were taken between 0600 and 0700 HR PST and again at 1400–1500 HR PST to determine weekly trunk radial increments and daily shrinkage. Final measurements of trunk radii were taken on 20 Dec. 1983. Additionally, the diurnal pattern of trunk radial shrinkage and swelling was monitored from 0500 HR 13 Sept. to 0500 HR 14 Sept. 1983 on four trees per irrigation treatment.

Return bloom in Spring 1984 was determined by counting flowers on nine 40-cm, randomly tagged, horizontal fruiting shoots in the top of each tree. All shoots were tagged 1 month prior to bloom. Mean return bloom was calculated, as well as percent fruit set and percent fruit drop.

In all trees, fruit were thinned to a commercially acceptable level in Apr. 1984. Fruit yield was determined in June 1984. Fruit harvest was based on maturity (ground color), and, as in most commercial orchards, involved three sequential harvests. Harvest dates were 13, 19, and 26 June. Mean yield per tree and mean fruit weight were determined for each treatment on each harvest date. To calculate mean fruit weight, two samples of ≈60 fruit each were taken at random from each tree on each harvest date. Fruit weight per sample was divided by the number of fruit to obtain mean fruit weight.

Results

Where it was possible to analyze for rootstock effects, no significant effects were found. Data from the three rootstocks therefore have been pooled for analysis of treatment effects.

Seasonal responses to irrigation treatments—water potential. For all three treatments, pre-dawn leaf water potential (ψ_w) remained relatively constant over most of the postharvest season (Fig. 1). The wet-treatment value was, with only slight variation, −0.3 MPa throughout the summer. Following irrigation on 8 Aug., medium-treatment pre-dawn ψ_w remained very similar to the wet treatment until mid-Sept., after which it decreased slightly. Dry-treatment pre-dawn ψ_w decreased steadily over the course of the postharvest season, but, by 1 Sept., was still only −0.65 MPa. Thereafter, however, it decreased more rapidly.

Seasonal trends of mid-day ψ_w are not as clear (Fig. 1). However, dry-treatment mid-day ψ_w was consistently more negative than either wet or medium treatments.

Leaf conductance. For all treatments, seasonal variations in both morning and afternoon g_l were considerable, but, on any given date, afternoon g_l was significantly lower than morning readings, regardless of treatment (Figs. 2 and 3). Dry-treatment conductances declined steadily over the course of the season, whereas wet- and medium-treatment conductances increased or decreased in response to irrigation and other environmental factors.

Radial trunk increase and shrinkage. The irrigation treatments had a substantial effect on seasonal trunk radial increment (Fig. 4). Wet-treatment trees exhibited a near-linear rate of increase over the course of the postharvest season. Although medium-treatment trees had a consistently smaller increase than wet-treatment trees, this difference was not significant. Dry-treatment trees showed a significantly reduced rate of radial increase as early as 3 Aug. and, by 20 Dec., a final increment only 71% that of the wet or medium treatments.

The seasonal pattern of daily trunk radial shrinkage also responded to the irrigation treatments (Fig. 5). Dry-treatment trees consistently had the greatest amount of shrinkage; this daily shrinkage increased as the season progressed.

Diurnal pattern of trunk radial shrink/swell. For all three treatments, the diurnal pattern of trunk radial shrinkage and swelling on 13 and 14 Sept. varied in proportion to the level of irrigation (Fig. 6). Dry-treatment trees had the greatest shrinkage and smallest increase in radial increment during the 24-hr period, whereas wet-treatment trees had the least shrinkage and greatest increase in radial increment. Medium-treatment trees had an intermediate response.

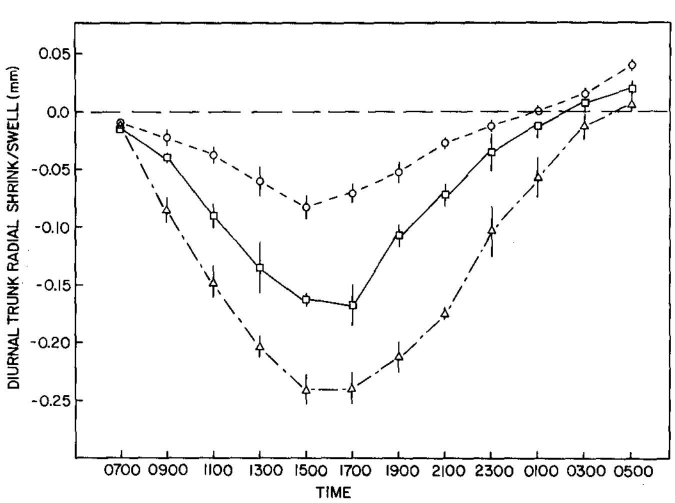

Fig. 6. Diurnal pattern of trunk radial shrink/swell on 13–14 Sept. 1983 in response to irrigation treatment. Circles = wet treatment; squares = medium treatment; triangles = dry treatment. Symbols represent means of four trees per irrigation treatment ± SE. Where not shown, SE bars are within the area of the symbol.

Influence of irrigation treatments on vegetative growth. For all trees, regardless of irrigation treatment, extension growth of all tagged shoots ceased soon after tagging. Therefore, no significant differences in shoot extension growth were found between irrigation treatments. However, basal diameter measurements of vigorous shoots and pruning weights at the end of the growing season did indicate small differences in the shoot growth responses of trees in the three treatments (Table 1). Significant differences in shoot basal diameters were found between wet and dry treatments, with the dry treatment value ≈85% that of the wet treatment (Table 1).

Influence of irrigation treatment on return bloom and fruit set. In the spring following the irrigation treatments, return bloom and fruit set were higher in the dry-treatment trees than in wet- or medium-treatment trees (Table 2). The dry treatment return bloom was 6.16 flowers per 40 cm of shoot. This frequency was 30% and 40% greater than in the medium and wet treatments, respectively, and represented a significant difference from either wet or medium treatments. There was no significant difference in return bloom between wet and medium treatments. Although there was no significant difference in the number of fruit set per 40 cm of shoot between wet and medium treatments, dry-treatment fruit set was significantly greater, having ≈70% more fruit set.

Influence of irrigation treatment on fruit yield. After fruit thinning in mid-spring, no significant difference in total yield was found among treatments, but fruit maturity in the dry treatment was delayed (Table 3), as evidenced by the different amounts of fruit harvested on each date. No significant differences in mean fruit weight were found among treatments, regardless of harvest date (data not shown).

Table 1. Influence of irrigation treatments on the basal diameter of all vigorous upright shoots and pruning weights at the end of the treatment period.

Irrigation treatment	Basal diam (cm)	Pruning wts (kg fresh wt)
Wet	1.49	29.29
Medium	1.30	26.79
Dry	1.27	25.38
LSD ($P = 0.05$)	0.08	4.59

Table 2. Influence of irrigation treatment on return bloom and fruit set, 1984.

Irrigation treatment	No. flowers/40 cm	Fruit set/40 cm	Percent fruit set
Wet	4.35	2.29	52.6
Medium	4.74	2.30	48.5
Dry	6.16	3.99	64.9
LSD ($P = 0.05$)	1.18	1.00	13.7

Table 3. Influence of irrigation on fruit yield (kg/tree), 1984.

Irrigation treatment	Harvest date			
	13 June	19 June	26 June	Total
Wet	26.6	51.0	30.6	108.2
Medium	29.1	49.4	28.8	107.3
Dry	14.7	56.2	48.6	119.6
LSD ($P = 0.05$)	10.0	14.8	18.4	28.2

Discussion

As the season progressed, there appeared to be a general relationship between decreasing leaf ψ_w and conductance in the dry and medium treatment (Figs. 1–3). However, it is difficult to determine whether ψ_w is regulated by leaf conductance or vice versa. Apparently, as tree water status decreased over the course of the season (dry treatment), or between irrigations (medium and wet treatments) (Fig. 1), stomata were regulated (Figs. 2 and 3) so as to reduce transpiration and prevent excessively low tree water potentials. Although medium- and wet-treatment water potentials were very similar after the medium-treatment irrigation on 8 Aug. (Fig. 1), medium treatment g_l decreased significantly thereafter (Figs. 2 and 3). Such a response is consistent with the concept that stomata function as a protective mechanism against excessive plant water loss (2). Similar responses of g_l and ψ_w to soil moisture deficits have been reported (4, 9, 10, 17, 19), and stomatal closure and subsequent reductions in transpiration and photosynthesis in response to water stress are well-recognized phenomena (1, 2, 13). This "strategy" of regulation of plant loss is apparently more pronounced in long-lived woody species than in certain herbaceous plants (5).

Nearly 6 weeks into its second drying cycle, the medium treatment showed no significant difference in mid-day leaf ψ_w from the wet treatment, which had been irrigated <3 weeks previously (Fig. 1). Stomatal conductance, however, was substantially different in these two treatments (Figs. 2 and 3). This difference is possibly due to increased resistance to water flow in the medium treatment. It has been shown for citrus that water stress alters the relationship between transpiration and ψ_w (8), presumably because of increased resistance in the stressed plants.

Diurnal trunk shrinkage results from a decrease in trunk hydration as transpirational loss exceeds water uptake during the day (14). Increased diurnal shrinkage of dry-treatment trees over the course of the postharvest season (Fig. 5) reflects the progressively reduced plant water potential in those trees (Fig. 1).

The capacity of the microdendrometer to detect small variations in diurnal trunk shrinkage and its relative ease of use suggest that it may be suitable as an instrument for indicating plant water status and for scheduling irrigation.

The lack of stress effects on secondary shoot extension growth is similar to the results of a study reported by Veihmeyer (19). He concluded that water stress occurred too late in the year to affect vegetative growth. Apparently, in 'Regina' peach trees, the bulk of shoot extension growth occurs in spring before harvest, and postharvest water stress is ineffective in reducing this growth.

Although extension growth was not affected, the tendency toward decreased dry-treatment primary shoot basal diameters, reduced dry-treatment pruning weights (Table 1), and marked reduction in trunk radial increase in the dry-treatment trees (Figs. 4–6) indicate an inhibitory effect of water stress on secondary growth (thickening) of both trunk and shoots. However, caution is necessary in analyzing the dendrometer (trunk radii) data, since measurements may reflect changes due to hydration or dehydration rather than actual cambial growth (14). Following rainfall or irrigation, significant portions of trunk radial increase can be attributed to a hydration component (14). Thus, although differences between treatments in trunk radii were greatest on 22 Sept. (Fig. 4), these differences presumably were due in part to variations in tissue hydration. Rehydration of dry-treatment trees between 22 Sept. and 20 Dec. by irrigation and rainfall eliminated the internal water stress and resulted in a less-pronounced, although still significant, reduction in dry treatment trunk radial increase (Fig. 4).

When comparing the dry treatment to the wet, the small or insignificant reductions in vegetative growth do not seem to agree with the stomatal conductance readings. Presumably, the significant reductions in seasonal g_l suggest substantial reductions in CO_2 assimilation, which should translate into greatly reduced growth. However, actual measurements of CO_2 assimilation were not made. In addition, measurements were not made of respiration and root growth, which could account for some differences in carbohydrate use.

Stimulation of return bloom in water-stressed trees has been reported (15), but other studies show an inhibition of flowering due to water stress (3, 11, 12, 18). Differences between species, and in the timing or severity of the stress, may explain these discrepancies. The increased bloom and fruit set and the delay in fruit maturity in dry-treatment trees could be due to differences in carbohydrate content, nutrient levels, hormone levels, or, more likely, a combination of factors.

Although postharvest water stress in 1983 achieved statistically significant reductions in secondary vegetative growth in both medium and dry treatments, and especially in the dry treatment (Table 1; Fig. 4), these reductions were too small to be horticulturally significant in terms of reducing pruning costs and controlling tree growth. However, substantial reductions in postharvest water consumption were achieved in both medium and dry treatments. Although the increased fruit set in the dry treatment could be economically disadvantageous, since additional labor would be required for fruit thinning, the medium treatment showed no increase in fruit set compared to the wet treatment. The delayed fruit maturity in the dry treatment also could be economically disadvantageous, especially in an early season cultivar; but, again, the medium treatment showed no delay in fruit maturity.

Thus, it appears that a single postharvest irrigation at midsummer, similar to that applied to the medium treatment, is adequate for maintenance of 'Regina' peach trees. As the medium treatment received only 50% of the postharvest irrigation given the wet treatment, there is considerable potential for water conservation in 'Regina' orchards, and, most likely, in other early season stone fruit cultivars. This potential for water conservation would be particularly valuable in drought years.

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