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The Effect of Reduced Water Supply on Peach Tree Growth and Yields[1]

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Abstract. **A range of irrigation levels was compared in specific periods of fruit development to determine their suitability for control of tree vigor and yields in ultra-dense orchards of peach [*Prunus persica* L. Batsch] trees. Where trees in the 3rd leaf were trickle-irrigated with 4 levels (100, 50, 25, and 12.5%) of replacement of E_{ps} (evaporation over the planting square) during the period of rapid vegetative growth, both frame and fruit growth declined as irrigation quantity decreased. In the following period of maximum fruit growth, 130% of E_{ps} replacement increased vegetative growth but not fruit growth compared to 100% E_{ps}. The fruit, however, grew faster in this period on those trees which had received low levels of E_{ps} replacement in the earlier period of maximum vegetative growth. The net result was similar final fruit size and yield between treatments, combined with control of vegetative growth at the lower levels of E_{ps}. A large saving in irrigation water was obtained at the lower levels of replacement of E_{ps}.**

Trees grafted onto dwarfing rootstocks generally have a high harvest index and when closely planted maintain a high level of production for many years (9, 10). Both long-term yield and ease of management depend on the selection of a rootstock which has a level of vigor that is compatible with the tree spacing selected. On the other hand the desirable characteristics of rootstocks which limit the ability of the tree to quickly fill its allotted space to some extend reduce the potential for early yield inherent in a large tree population. In an earlier high density experiment, we avoided the above limitation by controlling irrigation levels (3). Optimum irrigation enabled peach cuttings to quickly fill their allotted area, while from 2nd leaf onward, restricting the irrigation during carefully selected periods inhibited frame growth without reducing fruith growth. The management system produced an easily managed tree with a high harvest index and high early yield.

Water supply was controlled in relation to the stages of dry weight growth of the peach (2) and competing growth by the frame. The rate of dry weight growth of the 'Golden Queen' peach increases during the first (DW I) and last (DW III) stages of dry weight growth but decreases during the second stage (DW II). For this cultivar, DW II lasts for 40 days and in the Southern Hemisphere usually begins in early December. Since 2/3 of the peach fruit growth occurs during DW III, the initial growth of the fruit (in DW I to DW II) represents a relatively small proportion of the harvested yield. Conversely, for late season peaches the majority of tree growth occurs prior to DW III, and in a previous experiment (3) frame growth was controlled without depressing yield by restricting irrigation in DW I and DW II.

This paper reports an experiment designed to more closely define the above irrigation strategy. We investigated the effect of a range of irrigation levels prior to DW III and 2 levels of irrigation during DW III.

Materials and Methods

Experimental site and planting material. An area of 0.1 ha of Shepparton fine sandy loam (7) at the Irrigation Research Institute, Tatura, was selected for the experiment. Trees of 'Golden Queen' peach trees (clingstone) were propagated from hardwood cuttings taken in July 1978 and planted into the orchard (6) in November 1978 at 1-m spacings in rows 2 m apart. The results referred to in this paper are those of the first commercial harvest in March 1981.

Irrigation. All trees were trickle-irrigated, and in the first 2 years the quantity of water applied was calculated to give maximum frame growth (1). In the third year (1980–81) we imposed 6 irrigation treatments based on evaporation from a class A pan calculated for the area of the planting square of the tree (E_{ps}). The aim of the treatments prior to DW III was to establish a level of irrigation which would achieve control of frame growth without depressing final fruit size or yield. To this end, the treatments spanned a wide range of E_{ps} replacement, viz., 100, 50, 25 and 12.5%. During DW III the possibility of increasing fruit size by irrigation management was investigated. Two levels of E_{ps} replacement (100 and 130%) were compared, superimposed on 2 treatments irrigated prior to DW III with 25 and 50% replacement. The remaining treatments received 130% replacement in DW III.

We varied the irrigation level by adjusting the rate of water application during a constant time, and irrigating daily to the E_{ps} of the previous day. At the transition between irrigation levels at the start of DW III, all treatments were irrigated heavily to establish uniform wetting patterns.

Statistical design and measurements. The planting module consisted of blocks of 5 rows separated by 4-m-wide alleyways. The rows adjacent to the alleyway guarded plots of 3 rows of 4 trees each. Single trees guarded these plots units along the rows. The 6 treatments were replicated 4 times using a randomized block arrangement.

Tagged fruit were measured weekly from the first week in November until harvest. In addition, 20 fruit per plot were measured at random on January 12 and February 10 and 23. Trunk cross-sectional area (TCA) was estimated from trunk diameter in October, at the start of DW III and immediately after harvest. We summer-pruned all trees at monthly intervals from November 16 to February 16, inclusive, and weighed the prunings from the 4 trees in each experimental plot. Winter prunings (July) from all plot trees were also weighed. In both summer and winter the trees were pruned to regulate internal shading to the same level in all treatments. Although the density of the resulting canopy was judged visually, the amount of pruning required was proportional to the amount of shoot growth that had preceded pruning. Certainly prunings accumulated over the season from monthly summer pruning comfortably accounted for any small

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errors of judgement that may have occurred in a single pruning treatment.

Samples of soil for gravimetric determination of moisture present between 0 to 20 cm depth were taken from the center of the drip wetting pattern on 1 tree per plot on Jan. 6 and 8, 1981, immediately prior to irrigation.

Gross yield, canning yield (fruit diameter > 6 cm), and fruit number were determined at harvest.

Results

Tree growth. Trunk cross sectional area (TCA) is related to the aboveground weight of the tree (8) and the TCA increase is consequently related to the annual growth of the tree. The weight of summer prunings also relates to the level of tree growth and in this study both the above measurements indicate that more water consistently increased vegetative growth. Prior to DW III this effect was proportional to the quantity of water applied (Fig. 1). Moreover, both the TCA increase and the weight of summer prunings were significantly greater on trees receiving 100% E_{ps} replacement compared to the other treatments. Of the latter treatments, 50% E_{ps} replacement grew more than both the 25 and 12.5 E_{ps} replacement treatment. In DW III, more summer prunings were removed from the trees receiving 130% E_{ps} with a similar, nonsignificant trend recorded for TCA increase (Table 1). Similarly, more water increased the weight of winter prunings removed from the 130% E_{ps} treatment significantly. The weight of winter prunings did not differ significantly between treatments applied before DW III, but these weights were in the same order as those recorded for summer pruning and were 0.93, 0.86, 0.83, and 0.76 kg per tree for the 100, 50, 25, and 12.5% E_{ps} treatments, respectively.

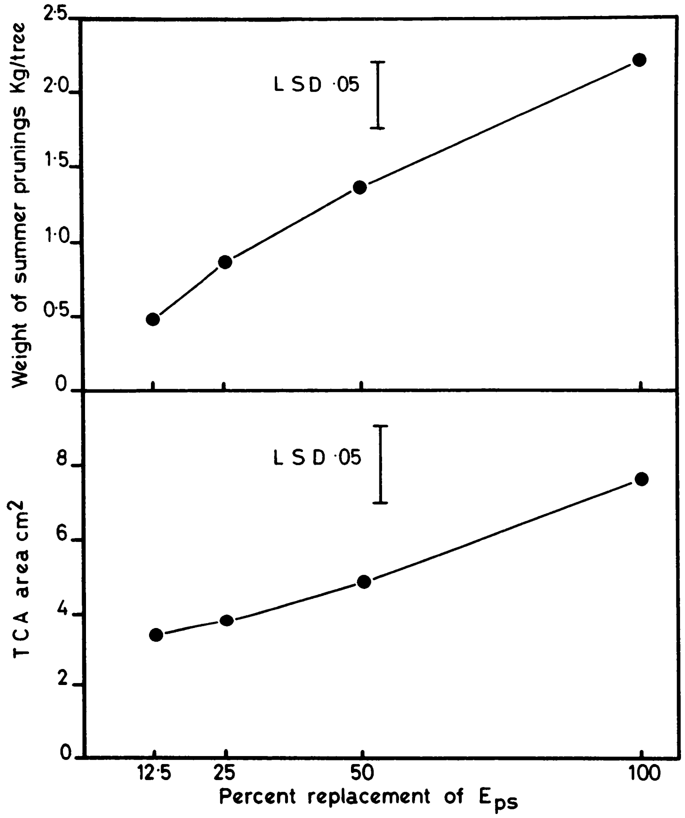

Fig. 1. Influence of irrigation treatment on TCA increase and fresh weight of summer prunings.

Table 1. Influence of irrigation in DW III on trunk cross-sectional area (TCA) and fresh weight of prunings.

Irrigation treatment (% replacement of E_{ps})	Jan. 1–Mar. 10 Mean TCA[z] increase (cm^2)	Jan. 16–Feb. 10 Weight of summer prunings (kg/tree)	Weight of winter pruntings (kg/tree)
130[z]	1.92	0.48	0.84
100	1.66	0.34	0.72
LSD 5%	NS	0.09	0.11
1%	NS	0.14	NS

[z] Estimated trunk cross sectional area (π/4 · d^2).

[y] Both 50 and 25% E_{ps} replacement prior to DW III split for 100 and 130% E_{ps} replacement.

[NS] Nonsignificant.

Fruit growth. The pattern of fruit growth was similar to that recorded in our previous experiment (3). Before DW III, the measurements of tagged fruit indicate that fruit on trees receiving the 100% E_{ps} treatment grew faster than the fruit on the 12.5% treatment (Fig. 2). Conversely, in DW III, although the growth of the tagged fruit was not significantly different between treatments, it tended to be slower on the 100% E_{ps} treatment. On the other hand, when the replacement level was increased to 130% in DW III, no further increase in fruit growth was obtained; the estimated volume increments being 72 cm^3 and 75 cm^3 for 130 and 100% E_{ps} treatments, respectively. The above effects of irrigation were also reflected in the size of the fruit sampled at random. The measurements taken immediately before DW III commenced (January 12) indicated fruit irrigated by lower levels of replacement were smaller, whereas by February 10 and 23 there was no difference in fruit size between treatments (Table 2). This result was confirmed at harvest (Table 3). Similarly, fruit measurements on February 23 failed to show any effect of irrigation level during DW III on fruit size. The yield per tree

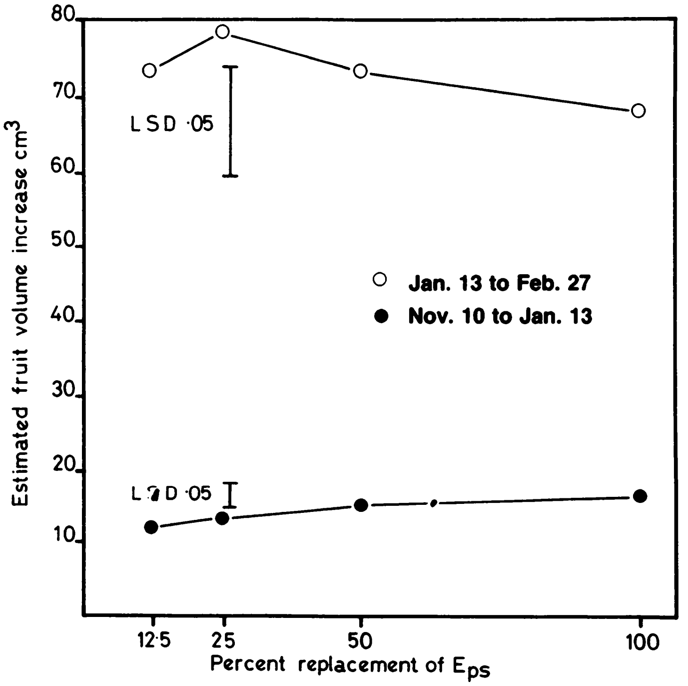

Fig. 2. Influence of irrigation treatment on growth of fruit measured weekly. Volume estimated from $4/3(\pi r^3)$.

Table 2. Influence of irrigation on fruit size.

Irrigation treatment (% replacement of E_{ps})	Mean fruit diam (cm)		
	Jan. 12, 1981	Feb. 10, 1981	Feb. 23, 1981
Prior DW III[z]			
100	3.79	4.63	5.48
50	3.66	4.64	5.48
25	3.54	4.61	5.55
12.5	3.44	4.55	5.47
LSD 5%	0.10	NS	NS
During DW III			
130	3.60	4.61	5.50
100	3.66	4.63	5.48
LSD[z] 5%	NS	NS	NS

[z] All treatments received 130% replacement of E_{ps} during DW III. Both 50 and 25% E_{ps} replacement prior to DW III split for 100 and 130% E_{ps} replacement.
[NS] Nonsignificant.

resulting from the above effects on fruit growth was similar for all treatments except the treatment irrigated with 12.5% E_{ps} before DW III. This latter treatment produced higher gross yields and more fruit per tree than any other treatment (Table 3). This difference, however, was due to tree size, since in October the TCA of the trees in the 12.5, 25, 50, and 100% replacement treatments were 19.1, 17.7, 17.0, and 17.1 cm^2, respectively. The trees were thinned according to tree size, and the fruit load per unit of October TCA indicates there was no difference in fruit load between treatments after thinning (Table 3).

Tree growth between October and the start of DW III altered the above tree size relationship. By January the crop load per unit TCA had become significantly higher on the 12.5 E_{ps} replacement treatment (compared with the 100% E_{ps} followed by 130% E_{ps} in DW III) with a related trend showing up in all other reduced irrigation treatments (Table 3). Further, where trees received 130% replacement compared to 100% replacement in DW III, the fruit load was 3.29 and 3.43 fruit per cm^2 TCA, respectively.

Gravimetric water. At both dates of sampling, the 100% replacement treatment was wetter than the other 3 treatments. At both dates the figures obtained from this treatment were close to the 20% moisture figure recognized as field capacity of the surface soil of a Shepparton fine sandy loam (5). Conversely, the moisture figures obtained from the remaining treatments were within 0 to 3% of wilting point (10%).

Discussion

This study substantiates our earlier work (3), in that a management system which restricts irrigation prior to DW III will reduce vegetative growth in a high-density planting without decreasing final fruit size or yield. The success of the 12.5% replacement treatment implies that there is a wide margin for safety in regulating irrigation to give maximum control of vegetative growth without decreasing canning yield. In the second year of our previous experiment, 30% replacement was too severe and reduced fruit set. In that experiment, however, we used long periods without water interspersed with periods of irrigation, whereas in this study all treatments received some water at each irrigation. This difference in the technique we used to drought the trees could explain the above anomaly; a small quantity of water applied daily preventing fruit drop, perhaps by avoiding excessively low tree water potential.

The results of both this and our previous study point to an important new option for management of high-density plantings in arid and semi-arid climates. Trees can be grown quickly to fill their allotted space with a high level of E_{ps} replacement. Once they have filled their space, a much lower level can be used to control tree size with no less and very likely a gain in fruit yield. Peach trees have been grown by the methods used in the first experiment (3) for 4 cropping years. They remain healthy and productive and have not overgrown their allotted space.

The optimum level of E_{ps} replacement will vary according to tree vigour, soil type, and the environment. Nevertheless, as the tree becomes older, vegetative growth will decline and irrigation levels may need adjusting. Consequently, research will be needed to adapt the principles developed here to other peach cultivars and localities. The possibility of using an approach similar to this to control vegetative growth of other fruit tree species also should be considered. The early stages of growth by other fruit also contributes relatively little of the final fruit weight, and therefore partial droughting may similarly reduce vegetative growth without seriously affecting yield.

Table 3. Influence of irrigation on fruit number, size, and yield.

Period of irrigation treatment		Gross yield (kg/tree)	Canning yield >60 mm diam (kg/tree)	Mean fruit wt (g)	Fruit no. per tree	Fruit no. at harvest/cm^2 TCA[z]	
Prior DW II	During DW III					Oct. TCA	Jan TCA
100	130	10.04	8.75	140	71.9	4.31	2.99
50	130	9.25	8.19	138	67.0	3.91	3.06
25	130	9.86	8.44	137	71.8	4.09	3.37
12.5	130	11.63	9.64	138	84.3	4.43	3.77
50	100	9.20	7.76	135	68.1	4.19	3.21
25	100	10.51	8.96	141	74.7	4.42	3.66
LSD 5%		1.01	1.10	NS	4.9	NS	0.65
1%		1.39	1.53	NS	6.8	NS	NS

[z] Estimated trunk cross sectional area ($\pi/4 \cdot d^2$)
[NS] Nonsignificant.

Vegetative growth was stimulated by too much water, even when it was applied while fruit are growing rapidly and competing strongly with the tree. Thus the higher levels of E_{ps} replacement during DW III stimulated vegetative growth without increasing fruit growth. This was a surprising result, since on mature trees, rapidly growing fruit strongly inhibit frame growth (4). It is likely that this effect was due to the fact that the trees were young and vegetatively vigorous.

All reduced irrigation treatments saved considerable water, and given the conditions of our experiment, a replacement of 12.5% E_{ps} to mid January followed by 100% replacement to harvest would require 6 megaliters of water/ha compared to 9 megaliters for 100% replacement throughout the season. Clearly, methods of irrigation based on this approach save considerable water and will prove to be highly suitable for fruit growing in areas with limited water.

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Postharvest Decay, Respiration, Ethylene Production, and Quality of Peaches Held in Controlled Atmospheres with Added Carbon Monoxide[1]

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***Abstract.* The effects of 11% CO added to air or to 4% O_2 ± 5% CO_2 on brown rot development, respiration, ethylene production, firmness, color, composition, and internal breakdown of peaches [*Prunus persica* (L.) Batsch cv. Fay Elberta] were evaluated during holding at 5°C for 14 days followed by 3 days at 20° in air. The addition of 11% CO to 4% O_2 ± 5% CO_2 atmospheres completely inhibited growth of *Monilinia fructicola* (Wint.) Honey *in vitro* and *in vivo*. However, the normal rate of rot development resumed once inoculated plates and fruits were transferred to air at 20°. CO added to air stimulated CO_2 and C_2H_4 production and enhanced softening, but its effects were insignificant when added to 4% O_2, 5% CO_2, or their combination. CA treatments without CO decreased respiration and C_2H_4 production rates and delayed softening. Differences among treatments in composition were small. Internal breakdown incidence and severity were slightly reduced by CO and increased by CO_2.**

The effectiveness of carbon monoxide (CO) as a fungistatic gas is pathogen dependent and is greatly enhanced when combined with reduced-O_2 atmospheres (7). The minimum concentrations required to achieve decay control appear to be 5% CO in less than 5% O_2 (6, 7, 15). Reduced O_2 alone did not influence growth of *Monilinia fructicola* (13, 15), but its growth and spore germination were suppressed by 10 to 20% CO_2 atmospheres (3, 16). Although CO_2 levels above 5% can harm peach fruit quality (2, 11), Anderson et al. (1) reported that flesh breakdown and discoloration were delayed by storing peaches at 0°C in a controlled atmosphere (CA) of 1% O_2 + 5% CO_2 rather than in air. Smith and Anderson (14) found that while CA slightly reduced decay on peaches during storage at 0°, it had no effect on their decay following transfer to 18.3°.

CO mimics C_2H_4 effects and can enhance fruit ripening when added to air (4, 8, 10). Kader et al. (9) reported that 5 or 10%

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