Reducing Water Use in Navel Orange Production with Partial Root Zone Drying

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Yields of 'Washington' navel orange trees receiving 25% and 40% less irrigation water than the well-watered control trees by either partial root zone drying (PRD), or conventional irrigation at reduced rates (CI-RR) were significantly reduced. The lower irrigation rates, independent of PRD or CI-RR, also reduced the yield of commercially valuable large size fruit. The negative effects of reduced irrigation on yield resulted when treatments were imposed July to January or January through December. This year to prevent the reduction in fruit size, the amount of irrigation water given to trees in the PRD and CI-RR treatments was increased to that of the well-watered control trees during August and September. With this strategy, fruit growth rate recovered for trees that previously received 50% PRD from January through July, resulting in fruit with an average diameter equal to that of the well-watered control trees by September, while using 27% less irrigation water than the well-watered control trees from January through September.

The California citrus industry produces "picture perfect" navel orange fruit for the fresh fruit market on 124,385 irrigated acres. The cost of irrigation water is a major expense associated with citrus production. Partial root zone drying (PRD) is an irrigation strategy designed to increase water-use efficiency in fruit tree crops to reduce production costs without reducing the current or return yield. PRD is the practice of alternately wetting and drying the root zone on two sides of the tree.

Our research goal is to test the feasibility of using partial root zone drying (PRD) to reduce the amount of water used in citrus production and, thus, increase grower net income. The specific objectives are: (1) to reduce annual water use in a commercial navel orange orchard by alternately wetting and drying the root zone on two sides of the tree using irrigation rates that are 25% or 40% less than the well-watered control under conventional irrigation (CI); (2) to compare the PRD treatments with CI at the reduced rates (CI-RR) of 25% and 40% less than the well-watered control and with the well-watered control; (3) to determine the effect of PRD and CI-RR treatments on soil moisture content to schedule irrigation; (4) to determine the effect of PRD and CI-RR treatments on total yield, fruit size and quality at harvest and return bloom for two crop-years; (5) to provide the initial soil moisture content values and number of calendar days for scheduling irrigation for PRD or CI-RR; and (6) to provide a cost:benefit analysis of the results.

The design is a randomized complete block with five replications of each treatment in a commercial navel orchard at the University of California-Riverside Citrus Research Center and Agricultural Experiment Station. The treatments are: (1) well-watered control (based on evaporative demand); (2) 75% PRD and (3) 60% PRD – trees have an emitter on each side that alternate in delivery to one side of the tree and then the other; (4) 75% CI-RR and (5) 60% CI-RR – trees have an emitter on each side of the five trees within the row so that both sides of the tree are wet. Soil moisture content is measured on each side of a data tree in each treatment for five replications. For years 1 (July-January) and 2 (January-December), controls were irrigated when soil moisture reached -30 cb at 30 cm; PRD

Table 1. Effect of reduced irrigation (75% and 60% of the well-watered control) by CI or PRD on yield and fruit size.

		Packing carton size[y]				
Treatment	Total	56	72	88	113	138
	---------- no. of fruit/tree ----------					
Control	1142.97 a[z]	27.91 a	100.97 a	263.08 a	374.33 a	375.59 a
CI-RR 75%	809.38 b	7.88 b	28.85 b	95.84 b	225.81 b	450.78 a
CI-RR 60%	107.93 c	0.36 b	2.76 b	14.40 c	27.79 c	62.62 b
PRD 75%	127.15 c	0.12 b	2.14 b	9.09 c	36.22 c	79.57 b
PRD 60%	130.03 c	0.52 b	2.04 b	14.80 c	33.83 c	78.84 b
P-value	<0.0001	0.0003	<0.0001	<0.0001	<0.0001	<0.0001

[y] Fruit sizes categories based on transverse diameters (cm): 138 (<6.35), 113 (6.35-6.89), 88 (6.9-7.49), 72 (7.5-8.09), and 56 (8.1-8.8).
[z] Values in a vertical column followed by different letters are significantly different at the specified *P*-value by Fisher's Protected LSD Test.

Table 2. Effect of reduced irrigation (75% and 60% of the well-watered control) by CI or PRD on total gallons of water applied and fruit size.

Treatment	1 Jan-31 Mar	1 Apr-30 Jun	1 Jul-30 Sep	12 Jun	13 Jul	28 Sep
	---------- cumulative gallons applied ----------			---------- fruit diameter (mm) ----------		
Control	26680	54365	71320	31.71 a[z]	42.75 a	57.17 a
CI-RR 75%	10180	41074	59686	28.49 ab	37.41 b	52.25 b
CI-RR 50%	9520	28502	51438	24.37 c	31.24 c	47.38 c
PRD 75%	14810	40800	59726	25.69 bc	33.77 c	48.88 c
PRD 50%	8370	27726	52095	29.81 a	38.81 b	57.07 a
P-value	NA	NA	NA	0.0077	<0.0001	<0.0001

[z] Values in a vertical column followed by different letters are significantly different at specified *P*-value by Fisher's Protected LSD Test.

and CI-RR treatments were allowed to dry to –60 cb before irrigation.

Washington' navel orange trees receiving 25% and 40% less irrigation water than the well-watered control trees from January to December by either PRD, or CI-RR had significantly lower total yield and yields of commercially valuable large size fruit (Table 1). The data indicate that the reduced irrigation treatments, independent of PRD or CI-RR, negatively impact fruit number (fruit set) and fruit size (fruit growth).

For the current year, trees in all treatments were irrigated when soil moisture reached -30 cb at 30 cm to reduce the severity of the water deficit experienced by trees in the PRD and CI-RR treatments, but to save additional water the 60% PRD and 60% CI-RR treatments were reduced to 50%.

From 1 January 2009 to 1 August 2009, PRD and CI-RR treatments delivering 25% and 50% less water per irrigation than the well-watered control reduced the total amount of irrigation water applied to 'Washington' navel orange trees by 25%

and 49%, and 25% and 48%, respectively (Table 2). For these treatments, there was a progressive decline in fruit size (transverse diameter), which was manifest in the trees receiving 50% CI-RR and 75% PRD by mid-June, but delayed for trees in the 75% CI-RR and 50% PRD treatments (Table 2). By mid-July, fruit size was significantly reduced for trees in all PRD and CI-RR treatments. Restoring the irrigation to PRD and CI-RR trees to the amount of the control trees for the months of August and September increased fruit growth. The size of fruit on trees in the 50% PRD treatment was not significantly different from the well-watered control trees by the end of September, despite the trees receiving 27% less water than the control trees through the end of September (Table 2). Although fruit produced by trees in all other reduced irrigation treatments remained significantly smaller than the control, the difference in size as a percent of the control was less in September than in July, providing further evidence that this strategy was beneficial. We plan to measure fruit diameter in October and, depending on the results, resume the reduced irrigation rates on 1 November to save additional water during the cooler months with no negative effect on fruit size at harvest in January 2010.

Publications

Research studying treatment effects on the yield of tree crops is not published without a minimum of three years of yield data.

Professional Presentations

This project and the results thus far were presented to stimulate a student discussion on plant responses to water-deficit stress in BPSC 143, upper-division undergraduate plant physiology.

Collaborative Efforts

The contributions of the UC Riverside Agricultural Operations staff and Mr. Eric Jorgenson to the success of our Prosser Trust project continue to be very important.

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