there during this season. Again visual differences in leaf drop between the controls and the oil treated plot appeared minimal and that no appreciable thinning occurred.

Treatments applied to the Bonanza navels in 1997 were more varied. Control plots for a second year in a row received no thinning treatments of any kind. Thinning treatments in 1997 included the following: heavy pruning to the plots which received 10 gallons/acre of Volck oil in 1996; no treatment in 1997 to the plots which received 15 gallons/acre of Volck oil in 1996; 30 gallons of Volck oil at petal fall to the plots which received 20 gallons/acre of Volck oil in 1996; a prebloom spray of 20 gallons of NR-415 oil to the plots which received 10 gallons/acre of NR-440 oil in 1996, a July application of 35 gallons of NR-440 oil to the plots which received 18 gallons/acre of 440 oil in 1996, and a petal fall spray of 30 gallons of NR-440 oil to the plots which received a 24 gallon/acre NR-440 oil application in 1996. Phytotoxicity of the treatments were again minimal except for the prebloom spray which caused substantial leaf drop and twig dieback. No significant differences in fruit size were found among treatments at harvest although there was a trend for all of the treatments to have a larger percentage of fruit size-88-or-larger then did the control plots. The control, however, did have a trend toward higher yield, both in fruit number and weight. A significant correlation was found between the average number of fruit-per-tree and the percentage of the fruit size-88-or-larger, reinforcing the observation that if the fruit can be thinned, the average fruit size will be larger.

Narrow Range 415 oil will be included in the experimental treatments at petal fall in 1998 based on the observation that the NR-415 oil applied prebloom resulted in much higher leaf drop as compared to petal-fall applications of the heavier oils. The ability to cause leaves and blossoms to drop prebloom may correlate with an ability to drop a portion of an excessive fruit load at petal fall.

Regulated Deficit Irrigation of Orange Under High Evaporative Demand

■ Project Leaders: David A. Goldhamer (209) 646-6500
Land, Air and Water Resources, UC/Kearney Agricultural Center, Parlier
and Mary Lu Arpaia
Botany and Plant Sciences, UC/Kearney Agricultural Center, Parlier

California's citrus growers face two major irrigation-related problems: 1) increased competition from the municipal and environmental sectors for a relatively fixed supply, and 2) high water costs. Traditional techniques to limit water losses (improve application efficiency) during irrigation, such as improved management of existing systems, adoption of more efficient methods (such as drip or microsprinkler rather than furrow), and better irrigation scheduling (not applying water in excess of potential tree water use) are all currently employed by growers to save water. However, there are limits to how efficiently one can irrigate. Thus, we continue to explore additional techniques to save water.

We are currently evaluating Regulated Deficit Irrigation (RDI). This technique purposely deprives trees of water during stress-tolerant times of the season. This stress causes the trees to partially close leaf stomata, thereby reducing transpiration (tree water use). The dilemma is that reducing transpiration also reduces photosynthesis, the process that provides the basic sugar building blocks for vegetative and reproductive growth as well as powering basic biochemical processes. The challenge of developing successful RDI regimes is to have reduced photosynthesis impact plant organs and processes that ultimately don't effect fruit yield or quality. Successful RDI would decrease irrigation costs without negatively affecting and possibly enhancing fruit yield and/or quality. For example, we've found that imposing a mild early July stress in almonds significantly reduces hull rot, a disease that kills shoots.

THE EXPERIMENT

We began this project in 1996 with Paramount Citrus as the cooperating grower. The trees are mature 'Frost Nucellar' on Troyer and are located east of McFarland. The trees have a rooting depth of about 24 inches and irrigation is by microsprinklers. The RDI regimes being evaluated are shown in Table 1 with 1996 applied water. In addition to a fully irrigated Control (35.9 inches), there are 14 regimes that vary the magnitude and duration of the deficit irrigation. This results in seasonal water use savings of from 7.2 to 34.1% (2.6 to 12.3 inches, respectively). Treatments 13 and 14 apply a uniform deficit throughout the season and save 25 and 15 percent of potential water use.

Each treatment is replicated 6 times. Each replicate contains 30 trees (3 rows of 10) with the interior 8 trees moni-

Irrigation Regime	Deficit Irrigation Period	Deficit Irrigation Level (% normal)	Seasonal Applied Water (inches)	Decrease from Control (%)
Control	None		35.9	
2	Mid May-Mid Jul	25	23.6	34.1
3	Mid May-Jun	50	30.5	15.1
4	Mid May-Mid Jul	50	29.1	18.8
5	July	0	25.1	30.0
6	July	25	32.7	9.0
7	July	50	32.6	9.3
8	July-Mid Aug	25	26.9	25.2
9	July-Mid Aug	50	32.4	9.6
10	July-Aug	25	24.3	32.4
11	July-Aug	50	29.9	16.8
12	Mid Oct-Mid Dec	0	32.6	9.3
13	Season	75	33.3	7.2
14	Season	85	33.0	8.0
15	Apr-Mid May	0	31.1	13.3

Table 1. RDI regimes and actual 1996 applied water.

tored. Numerous measurements are taken every 10 days including predawn and midday bagged leaf water potential, fruit diameter (tagged fruit), fresh and dry fruit weight (sampled fruit), and soil water content. Beginning in September, fruit color is monitored.

Four trees/plot are harvested in both January and March. All fruit is run through a commercial-like pack line to determine fruit number and machine-rated grade. Samples are taken of a mid size and hand evaluated for visual peel defects. All fruit characterized as "Choice" or "Juice" are further characterized. Each non-"Fancy" fruit is grouped based on its primary defect: 1) Puff and crease, 2) insect, or 3) developmental factors. One box of mid size fruit is put in cold storage for evaluation of post-harvest parameters.

FIRST YEAR RESULTS

Fruit growth with time is shown in Figure 1 for two mid season stress treatments. Irrigation is reduced during July for T5 and T6; 0 and 25 percent of normal, respectively. Note that fruit development decreases soon after irrigation is reduced and the magnitude of the reduction is directly related to the deficit irrigation. By withholding irrigation during July (T5), fruit growth stops entirely (size remained constant with time). However, immediately after full irrigation resumed in August, fruit growth appears to accelerate for the previously stressed treatments. This rapid growth occurs only for a short period and although this narrows size differences relative to the control, some size reduction is apparent even at the end of the season. The accelerated fruit growth is due almost entirely to rehydration of the previously stressed fruit, not dry matter accumulation.

Effects of the different RDI regimes on puff/crease for the March, 1997 harvest are shown in Figure 2. Early season stress (T2 and T15) reduced puff/crease; 12.4% of all fruit in the Control had puff/crease vs. 1.2% in T2. On the other hand, early stress did not decrease peel problems characterized as developmental, such as sunburn, sheep nose, and ridging (Figure 2). It should be pointed out that

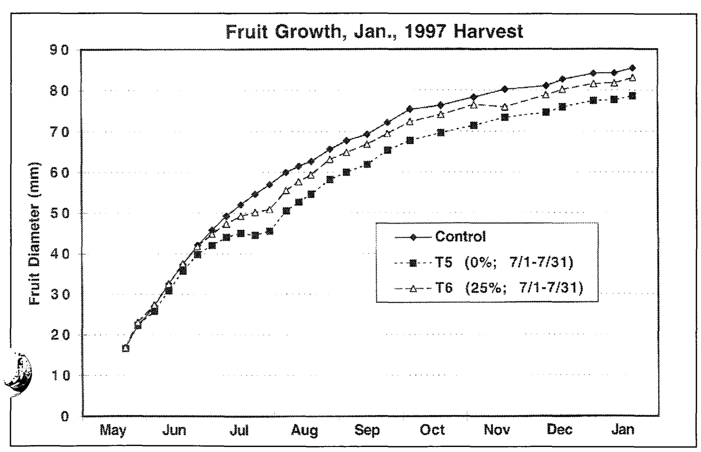

Figure 1. Fruit growth with time for equal fruit load trees.

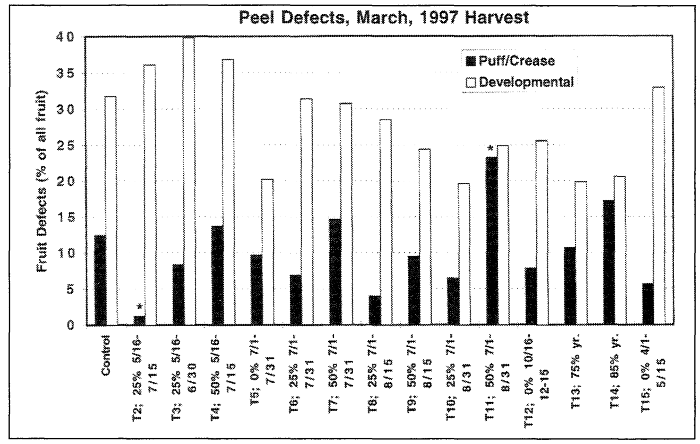

Figure 2. Characterization of March, 1997 harvest defects resulting in "Choice" or "Juice" grade. Asterisks indicate statistically significant differences from the control.

the early stress also seemed to increase fruit drop, resulting in lower fruit loads.

The bottom line results of any applied research are effects on profitability. We calculated mean gross revenue for both the January and March 1997 harvests based on the number of boxes of each fruit size produced per treatment and an average price per box for January and March, 1997. Gross revenue is plotted against actual 1996 applied water in Figure 3. Included in the figure is a line representing a one-to-one relationship between gross revenue and applied water. Previous work with other crops has shown that indiscriminate deficit irrigation (not timing stress to particular stress-tolerant periods) results in yield losses similar in magnitude to the irrigation deficit. For example, if the plants are deprived of 20% of their potential water use, yield can be expected to be reduced by 20%. We recognize that citrus revenue depends not only on yield but also on fruit size. Thus, one would expect that the actual revenue production function might be curved, with the slope increasing at the higher applied water levels.

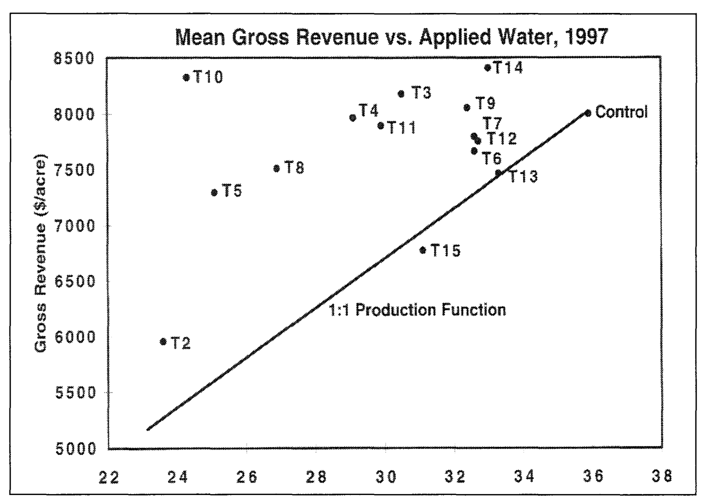

Figure 3. Mean (Jan. and Mar. harvests) gross revenue compared with actual applied irrigation in 1997. Solid line shows expected performance if relationship was one to one.

Technicians use pressure chambers to simultaneously measure leaf and stem water potential; both indicators of tree water stress.

Note that many of the RDI regimes fall above the one-to-one line in Figure 3. For example, T4 (Mid May-Mid July irrigation at 50% of normal) produced nearly the same gross revenue as the Control (near $8,000/acre) but used 18.8% less water. While T10 (July-August irrigation at 25% of normal) out produced the Control with 32.4% less water, this was due primarily to a higher fruit load. We believe that in-field variability was responsible for this rather than the RDI. One RDI regime produced less revenue than suggested by the one-to-one relationship, T15 (delaying irrigation until mid May). This was due almost entirely to a lower fruit load, presumably the result of the RDI.

We emphasize that the results reported herein are from the first year of this project. Continued observations are necessary before any definitive conclusions can be made. Nevertheless, RDI at this point appears to be a promising technique to save water in citrus while maintaining top yields of high quality fruit.

Development of an Integrated Farming System for Citrus and Its Comparison to a Conventional Farming System

■ Project Leader: Neil O'Connell (209) 733-6363
UC Cooperative Extension, Tulare County

Concern about ground water quality, resistance to registered pesticides and costs of production have lead to increased interest in biological farming systems. Interest in the use of cover crops as an orchard floor management strategy has been part of this interest in biological systems. Historical information suggests that vegetation may interfere with heat exchange and may result in lower temperatures than a bare soil free of vegetation. Citrus producers have been particularly concerned about this potential and increased frost risk.

Cover crops were planted in November of 1996 in three commercial citrus orchards to add to our knowledge of the impact of cover crops in citrus production. Perennial species (including fescues, clovers, brome and alfalfa) were planted in a block of twenty year old Valencia oranges under low volume drip irrigation. Cover crop growth was established uniformly across the planted middles during the winter rainfall period; during the summer the growth was sustained in the zone wetted by the drip line on either side of the tree. Two additional locations were planted; in each case a mix of Lana vetch, bell beans and oats was planted. The first of these locations was a thirteen year old block of Valencias with microjet emitters in the row. Vegetation was sprayed in the tree row, but volunteer growth was allowed to establish in the middles and then mowed in the spring. The other location was a twenty five year old Valencia orchard with microjet emitters in the row. Vegetation in the middles was allowed to volunteer in the winter and then burned off in the spring with a contact herbicide. In both of these locations growth of the cover crop was allowed to mature and then die back as moisture in the middles from winter rainfall was depleted.

In the first of the three locations two treatments were imposed: an eight row wide strip of cover and an eight row weed free area. Each treatment was replicated three times. In the second and third locations the volunteer vegetation was allowed to establish during winter rainfall period to reduce the herbicide load and additionally in the third site to reduce runoff and erosion. Cover and volunteer strips were eight rows wide with three replications in these two sites as well.

Stored soil moisture was measured with a neutron moisture meter with measurements taken in the tree row as well as in the middles. Tensiometer measurements in the same locations provided additional data on soil moisture conditions in the cover and control treatments. Water infiltration rate was measured m the wetted zone of the drip emitters in the cover and bare ground in the first location. Air temperature was recorded every thirty minutes by data loggers mounted five feet above the orchard floor. Sampling for Phytophthora and citrus nematode was conducted in late summer. Monitoring tubes were installed to measure nitrogen moving below the root zone. Leaf samples were taken periodically and analyzed both with a field meter and by laboratory analysis to evaluate the suitability of the meter for field estimates of nitrogen levels. Sampling was carried out on a weekly basis for pest and beneficial arthropods from March through mid October.

Five nights were recorded with a minimum temperature of 32 degrees or below from January to mid March. There was no significant difference in the duration measured in the first location between the cover crop and the weed free treatment.