

CT0115

Winter Irrigation of the Navel Orange

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Summary

The objectives of the present study were to quantify the effect of withholding irrigation during the winter season in Southern California on the productivity of the Washington navel orange and to determine whether the additional expense of irrigating navel orange trees during the winter is a cost-effective production management strategy.

Yield and fruit size were quantified for 30-year-old Washington navel orange scions on Troyer citrange rootstock which were rain-fed from October 1 through March 1 in each of three successive years and for another set of trees which were irrigated during the winter. Supplementing winter rainfall with irrigation significantly increased the kg of fruit per tree in all three years of the study (45 ± 17 kg fruit tree⁻¹, n=3 years) and number of fruit per tree in the two years in which the rain-fed, -winter irrigation trees had significantly lower predawn water potentials than the +winter irrigation trees.

Despite the yield increases which resulted from supplementing winter rain with irrigation in each year of the study, there was no reduction in the number of commercially valuable fruit with transverse diameters between 7.0 to 8.0 cm in any year ($P < 0.05$). Irrigation treatment did not affect tree nitrogen status. Trees receiving winter irrigation to supplement rainfall were less affected by a preharvest freeze:

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compare a 50 percent reduction in yield from the previous year for the +winter irrigation treatment to a 93 percent reduction for the -winter irrigation trees.

Even in the year that the lowest net increase in yield was obtained with greatest amount of irrigation water valued at a high cost for California, winter irrigation was a cost-effective management strategy for the production of the Washington navel orange.

Narrative

High quality water at an affordable price is becoming increasingly limited in many crop production areas of the world, including California (Takele et al., 1995). Where surface water is available, it is often contaminated with salt. Many growers rely on underground aquifers, but these are being depleted more rapidly than they can be recharged (Kingsolver, 1986).

Worldwide, shortages in water available to agriculture are likely to become chronic due to increased urban and environmental demands. For example, due to years of drought, increased competition for available water, and regulatory restrictions on water supplied to agriculture, the cost of water to citrus growers in San Diego County, California, averages \$4,942 per hectare per year (Gary Bender, UC Farm Advisor San Diego County, personal communication).

As water costs associated with citrus production have increased, growers worldwide have sought ways to save water while minimizing or eliminating negative effects on yield and revenue. Researchers have attempted to identify specific times in the phenology of the citrus tree during which water deficits can be imposed without negatively impacting fruit number, size or quality to enable growers to reduce

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irrigation water consumption (Hilgeman and Sharp, 1970; Du Plessis and Du Plessis, 1987; Cohen and Goell, 1989; Goell, 1993).

Regulated-deficit irrigation is an irrigation scheduling strategy that is designed to save water while having a minimum impact on tree productivity. This is accomplished by imposing waterdeficit stress during phenological periods or seasons when the tree is relatively tolerant to stress (Goldhamer and Beede, 1995).

Identification of phenological stages that are tolerant or less sensitive to water deficits is required in order for growers to make irrigation management decisions based on cost-to-benefit analysis of yield and fruit quality versus water saved. The technique of regulated-deficit irrigation has been investigated with deciduous tree crops (Chalmers et al., 1984, 1986; Mitchell et al., 1984, 1989; Li et al., 1989; Boland et al., 1993; Lampinen et al., 1995), but to our knowledge, not with citrus.

In the absence of the basic information required to utilize regulated-deficit irrigation in citrus production, growers in Mediterranean climates have opted to save water and money by withholding irrigation during the winter when citrus grown in such climates is typically dormant, the crop has achieved near maximum size, evaporative demand is low, and there is the greatest likelihood of rain.

The present study was undertaken: (I) to quantify the effect on tree productivity of withholding irrigation during the winter season, a time when the Washington navel orange tree is relatively tolerant to stress; and (II) to determine whether the additional cost of irrigating during the winter is cost-effective as a management strategy for the production of the navel orange.

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Yield and fruit size were quantified for 30-year-old Washington navel orange scions on Troyer citrange rootstock which were rain-fed from October 1 through March 1 in each of three successive years and for another set of trees which were irrigated during the winter to supplement the rain.

In year two of the experiment, there was a freeze in December prior to harvest. Thus, the results of this research also provide data on the effect of the two irrigation management strategies on the yield loss caused by the freeze and on the return yield the following year.

Results and Discussion

Water-deficit stress is generally associated with reduced productivity (Bradford and Hsio, 1982.) However, some beneficial effects of water deficits have been reported for a number of fruit tree crops. Withholding irrigation followed by regulated deficit irrigation reduced vegetative shoot growth and pruning costs and increased yield of peach and pear (Mitchell and Chalmers, 1982; Mitchell et al., 1984; and Chalmers et al., 1984).


For citrus grown in tropical and subtropical areas with distinct rainy and dry seasons, water-deficit stress substitutes for low temperature in flower induction (Cassin et al., 1969; Reuther and Rios-Castano, 1969; Reuther, 1973). Water-deficit stress is used commercially to induce off-season flowers and fruit in lemons and limes, typically with no negative effects on number, size or quality of the existing crop. However, excessive stress has been documented to cause significant abscission of new flowers (64 percent) and reduced development of the current crop (Shalhevet and Levy, 1990). For sweet oranges, water-deficit stress during Stage I of fruit growth (cell division) reduces the

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number of fruit set, but the negative impact of water deficit on fruit size is often off-set by the early decrease in fruit number (Du Plessis and Du Plessis, 1987).

Water stress during Stage II of fruit development (cell expansion) strongly affects fruit size. It is during this stage that the greatest rate of fruit growth takes place (Bain, 1957; Holtzhausen, 1972). Cohen and Goell (1989) demonstrated that fruit growth rate was a good indicator of irrigation needs. Water stress during Stage II of fruit development while not as critical, still can affect size and number negatively (Du Plessis and Du Plessis, 1987).

Comparison of yield results obtained in this study on the basis of kilograms fruit, number of fruit, or number of commercially valuable fruit with transverse diameters between 7.0 to 8.0 cm per tree for +/-winter irrigation treated trees provides no evidence of any benefit from withholding irrigation from October 1 to March 1. Withholding irrigation resulted in statistically significantly less kilograms fruit per tree in all three years of the study, even in year No. 1 when tree predawn water status was not significantly different from that of trees in the +winter irrigation treatment during the period October through March and despite the fact the water deficits incurred in subsequent years were only moderate (approximately -2.5 MPa).

Trees that were not irrigated during the winter were affected more negatively by the preharvest freeze, yielding only 12 percent of the +winter irrigation trees in terms of both kilograms and number of fruit per tree and only 60 percent of the return crop. In all three years of the study, the lower yields of the trees not receiving winter irrigation never resulted in a significant increase in the number of largersized fruit, i.e., 6.1 to 8.0 cm in diameter. 

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In contrast, ~~the~~ statistically significant increases in yield were obtained in all three years of the study (an average 45 ± 17 kg tree⁻¹ yr⁻¹, n=3) with an accompanying increase in larger fruit (6.1-8.0 cm in diameter) by supplementing winter rain with an average of $30,282 \pm 7,866$ (n=3) liters of water per tree per year. Depending on the value of the crop and cost of irrigation water, this may or may not result in a significant increase in net return to the grower.

Nitrogen is typically applied to the soil in the winter in California to coincide with the rains. While there has been considerable speculation on the amount of this N that is actually used by the citrus tree, especially in years of drought, supplementing winter rain with irrigation did not elevate the nitrogen status of the navel orange trees in this research. Even for leaf samples collected in September of the third year of the experiment, there was no cumulative effect of withholding winter irrigation the previous winters on leaf total nitrogen concentration. Trees in both treatments averaged 2.5 percent N. Thus, the yield differences between the +/-winter-irrigated trees were not due to an effect of irrigation treatment on the uptake of soil-applied nitrogen. ✓

The results of the present study are the first to demonstrate the potential benefit of supplementing winter rainfall with irrigation to enhance the yield of the Washington navel orange. Even in years when withholding irrigation from October 1 to March 1 did not cause a significant difference in tree predawn water status after November (year No. 1) and freeze was not a factor (year No. 1), winter irrigation resulted in a net increase of 27 kilograms fruit per tree (1.6 packing cartons tree⁻¹) with no reduction in fruit size. This year which had the smallest net increase in yield but was irrigated with the greatest amount of water from October 1 to March 1 (44,151 liters tree⁻¹) was used to estimate the cost effectiveness of the treatment. A high value of \$81 per 1.0×10^6 liters of water resulted in cost of \$3.58 per tree to yield a net increase of 1.6 packing

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cartons of fruit with a value from approximately \$3 to \$6 per carton. Thus, supplementing winter rain with irrigation can be a cost-effective management strategy for navel orange production.

During the period December through February, flower initiation and organogenesis take place in Southern California. The period from October to harvest (the last week of January to the last week of February for the three years of this study), encompasses the transition from Stage II, the cell expansion phase of fruit growth, which is sensitive to water deficit (Cohen and Goell, 1989), to Stage III of fruit development, which is less sensitive (Hilgeman and Sharp, 1970; Du Plessis and Du Plessis, 1987).

In the third and final year of the research, trees in the -winter irrigation treatment received no irrigation during flower initiation and the early stages of flower development, but were irrigated during stage III of fruit development in the same manner as the trees in the +winter irrigation treatment. Despite this, the -winter irrigation trees had 40 percent less kilograms of fruit per tree, suggesting that the flowering process is more sensitive to water deficit than the last stage of fruit development.

Further research is required (I) to determine whether there is one, or more, smaller window within the period October 1 to March 1 that is more sensitive to water deficit or whether it is essential to maintain irrigation for the duration of this period; (II) to quantify the minimum amount of water required to achieve the tree water status necessary to attain the maximum possible increase in yield and fruit size; and (III) to identify additional stages in the phenology of the navel orange that are sensitive or tolerant to moderate water-deficit.

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