# Water conservation and management for foothill orchards

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When winter rainfall failed to refill reservoir reserves for the 1976 season, the El Dorado Irrigation District initiated an irrigation management program to improve efficiency of agricultural water use in El Dorado County. Analysis of data collected on the 1976 program suggested that there were considerable opportunities for water conservation in irrigation. The drought the following year forced the district to ration water to deciduous fruit growers at 2.3 acre-feet per acre, and this focused attention on the need to investigate the irrigation requirements of the county's orchards. The EID then requested Cooperative Extension to determine the evapotranspiration (ET) of deciduous orchards and to study the effects of reduced water supply on orchard performance.

These studies on water conservation became vitally important when the County Planning Department projected that, because of population growth, demands could exceed available water supplies after 1982, even in normal rainfall years. The studies were also needed to adapt and calibrate locally the Irrigation Management Service (IMS) that the EID had adopted, based on programs developed by the U.S. Bureau of Reclamation. For various reasons, growers had not fully utilized the free service provided for scheduling their irrigations. Variability in climate and soil of foothill orchards demanded information to improve IMS predictions on when to irrigate and how much water to apply, thus promoting acceptance of irrigation recommendations among growers.

Selected results are reported from 1977 and 1978 experiments on the ET requirements of El Dorado County pear and apple orchards, as well as on the tree responses to drought imposed by limited irrigation.

## Procedures

Foothill orchards are normally irrigated by portable or permanent sprinkler systems. Four orchards with permanent systems were chosen to represent several foothill environments. Results from two of the experimental orchards irrigated with permanent, over-tree sprinkler systems are reported here. Gene Bolster volunteered a portion of his apple orchard, located at 3200 feet of elevation, to investigate tree responses to limited irrigation. Treatments included seasonal amounts of irrigation of 3, 2.3, 1.5, and 1 acre-feet per acre, replicated three times. At least one replicate was on a north-facing slope and another was southerly exposed.

The effect of cover-crop removal on orchard ET was studied on Bert Marchini's pear orchard under two irrigation regimes, 3 and 2.3 acre-feet per acre. Each treatment was replicated twice. Applied water was measured with cans located around selected trees where the soil water content and potential were monitored with a neutron meter and tensiometers. Because of lack of winter rains, the subsoil's dry condition in 1977 allowed for accurate estimation of ET based on records of applied water and of soil water depletion. Fruit growth, leaf water potential, and leaf conductance were measured as well as total yields, fruit weight, and quality at harvest.

## Results

**Evapotranspiration and yields.** Table 1 summarizes experimental results in a pear and an apple orchard. In 1977, because of the lack of available moisture in the soil profile, the ET demand was not met until the end of August in any pear orchard treatment. This deficit resulted in tree water stress which was partially responsible for reduced fruit size. However, 1977's heavy fruit load resulted in overall higher yields than those obtained in 1978. In 1978, when applied water was adequate, the ET data for the pear orchard with a cover crop showed a seasonal increase in water use of about 1 acre-foot over a treatment where the cover crop was removed. This figure was confirmed by reviewing data from other orchards included in the IMS program.

The response of the apple orchard to reduced irrigation is also presented in table 1. In 1977, with very little water stored in the profile, applied water was nearly equal to ET for all but the 3 acre-feet treatments. However, fruit size in trees with similar fruit load was dramatically reduced as ET decreased because of water stress. Within treatments, the replicates located on the north-facing slope were less affected by the reduced applications because of lower evaporative demand. In 1978, the soil profile was fully charged at the beginning of the season; thus, the contribution to ET from stored soil water in the 1 acre-foot treatment was nearly 7 inches compared with just 1 inch in 1977. This significant contribution from stored soil water resulted in a large increase in fruit size in the 1 acre-foot treatment for 1978. Measurements of soluble solids and fruit pressure in the various treatments in the apple orchard showed for both years an increase in soluble solids and pressure with reduced water application.

**Soil water regime.** Irrigation scheduling techniques require knowledge not only of the orchard ET but also of the allowable depletion levels; these in turn depend on numerous soil, plant, and climatic factors. Soil water depletion was monitored using the neutron probe bi-weekly during the irrigation season. Very close to the neutron probe site, tensiometers were installed at 18, 30, and 48 inches deep. Figure 1 presents 1978 data on the soil water potential (tension) at 18 inches for three treatments of the pear orchard. Rate of increase in soil water tension was significantly affected by the cover crop and by the amounts of water applied. Treatments where the soil water tension at 18 inches did not exceed 60 centibars had larger fruit size. Measurements of fruit growth and of plant water potential indicated that soil water tensions exceeding 50 to 60 centibars at the 18-inch depth resulted in significant tree water stress. This observation plus long-time experience with tensiometers in foothill orchards led to our tentatively recommending the 60 centibar value at the 18-inch depth as the threshold for determining when to irrigate the orchards under the IMS scheduling program. It was recognized that this value will fluctuate, depending on each orchard's characteristics. The soil water depletion for the whole profile is now being correlated to the 60-centibar tensiometer reading at every neutron probe site.

**Physiological responses to water stress.** The physiological responses of apple and

**TABLE 1: Results of Experimental Irrigation of Pear and Apple Orchards, El Dorado County, 1977-1978**

| Crop | Time Period | Treatment | Applied Water | ET | Fruit size | Soluble solids | Pressure |
|---|---|---|---|---|---|---|---|
| | | | (in) | (in) | (#/100 Fruit) | (%) | (lbs) |
| Pears (Marchini) | 1977 (6/10-10/12) | 2.3 ac.ft. cover crop | 22.9 | 23.5 | 23.2 | 13.6 | 19.0 |
| | | 2.3 ac.ft. w/o cover crop | 21.8 | 20.8 | 24.6 | 12.6 | 19.2 |
| | | 3.0 ac.ft. cover crop | 26.1 | 24.8 | 26.7 | 13.7 | 18.1 |
| | | 3.0 ac.ft. w/o cover crop | 23.6 | 22.1 | 27.1 | 13.7 | 17.6 |
| Pears (Marchini) | 1978 (5/1-10/12) | 2.3 ac.ft. cover crop | 25.1 | 30.7 | 34.1 | 12.6 | 18.9 |
| | | 2.3 ac.ft. w/o cover crop | 24.4 | 25.2 | 39.6 | 11.6 | 20.0 |
| | | 3.0 ac.ft. cover crop | 35.9 | 35.9 | 37.7 | 11.9 | 20.0 |
| | | 3.0 ac.ft. w/o cover crop | 28.2 | 24.1 | 38.2 | 11.3 | 20.1 |
| Apples (Bolster) | 1977 (7/8-10/14) | 3.0 ac.ft. | 25.4 | 22.5 | 26.2 | 14.3 | 17.3 |
| | | 2.3 | 23.3 | 23.7 | 25.2 | 16.4 | 15.1 |
| | | 1.5 (north) | — | — | 26.3 | 17.2 | 17.8 |
| | | 1.5 (south) | 15.2 | 14.9 | 17.1 | 17.9 | 19.0 |
| | | 1.0 (north) | 9.6 | 9.5 | 20.7 | 16.9 | 18.5 |
| | | 1.0 (south) | 10.5 | 11.7 | 13.5 | 18.7 | 20.5 |
| Apples (Bolster) | 1978 (5/1-10/12) | 3.0 ac.ft | 33.9 | 32.1 | 29.5 | 12.5 | 16.9 |
| | | 2.3 | 25.7 | 29.4 | 29.0 | 12.7 | 16.2 |
| | | 1.5 (north) | 15.2 | 20.7 | 31.2 | 13.0 | 16.8 |
| | | 1.5 (south) | 17.6 | 23.6 | — | — | — |
| | | 1.0 (north) | 15.4 | 20.9 | 30.8 | 13.4 | 17.1 |
| | | 1.0 (south) | 13.0 | 19.9 | 22.3 | 15.0 | 18.6 |

pear trees to various applications of water were evaluated in 1977 by measuring leaf water potential with a pressure chamber and leaf conductance with a diffusion porometer. Leaf water potential indicates the energy status of the water in the leaf. The lower (more negative) the leaf water potential, the higher the degree of tree water stress. Leaf conductance indicates the degree of stomatal opening, which, by closing in response to water stress, decreases the transpiration rate. Stomatal control of transpiration, shown by a decrease in leaf conductance, usually results in reduced photosynthesis since intake of carbon dioxide and rate of water loss are both affected by stomatal closure.

Leaf water potential was measured on fully exposed leaves between 1100 and 1500 hours throughout the season. Four to six measurements were taken on selected apple and pear trees in each irrigation treatment.

Figure 2 presents the seasonal course of the leaf water potential of southerly exposed apple trees in Bolster's orchard. There were distinct differences in this parameter as a result of the variation in applied water from 1 to 3 acre-feet. Leaf water potential became more negative in the stressed treatments, being 10 bars lower in the 1 acre-foot treatment, compared with the 3 acre-foot. Nonírrigated trees in the same orchard exhibited midday leaf water potentials even several bars lower than those of trees in the driest treatment (figure 2). Very little difference was detected between the leaf water potentials of the 2.3 and the 3 acre-foot treatments. Figure 2 shows that tree water stress increased as applied water was decreased. Water stress also affected the leaf conductance of apple trees (figure 3). Leaf conductance of trees in the 1 acre-foot treatment was significantly lower than that for the other treatments, indicating partial stomatal closure. Stomatal conductance was reduced by water stress in the 1.5 acre-foot treatment and exhibited a seasonal decrease in both the 2.3 and 3 acre-foot treatments, perhaps because of leaf aging.

Measurements of water potential in Marchini's orchard were begun in early June, although effects of the differential treatments were not studied until July. The delay in starting irrigation induced water stress in all treatments in June. In the 2.3 acre-foot treatment with a cover crop, water stress was more extreme with leaf water potential having the most negative stress throughout the season. For all treatments, leaf water potential increased towards the end of the season because of both increases in water applied and decreases in evaporative demand. The low leaf water potentials induced partial stomatal closure only in the 2.3 acre-foot with cover crop treatment where the leaf conductance was significantly lower than in the other three treatments.

**TABLE 2. Effect of the Cover Crop on the Leaf Water Potential of Pear Trees June, 1977.**

| Treatment | Leaf Water Potential (Bars ± Standard Error) |
|---|---|
| A) Orchard with cover crop* | −27.5 ± 0.4 |
| B) Clean, cultivated orchard | −22.4 ± 0.4 |
| C) Orchard recently irrigated | −19.6 ± 0.5 |

*Treatments A and B unirrigated.

The effect of the cover crop on leaf water potential of pear trees was evaluated early in the season before the first irrigation. The results presented in table 2 show that trees under a cover crop underwent significant water stress, while unirrigated trees in a clean, cultivated orchard nearby had leaf water potentials nearer to those of trees that have just received a first irrigation.

Fruit enlargement was also found to be sensitive to water stress, in agreement with other studies. Figure 4 shows the fruit growth plotted against time for Bolster's in 1977. Fruit growth rates were markedly slowed by water stress in the 1.5 and particularly in the 1 acre-foot treatment (both southerly exposed). Our measurements, however, started where a significant difference in fruit size had already been established.

## Conclusions

Based on our experimental data and evaluation of IMS program data, we have concluded that seasonal orchard ET can be expected to vary from less than 20 inches in a northerly exposed orchard without a cover crop at 3500 feet elevation, to more than 40 inches for a fully exposed orchard with a cover crop at 1500 feet elevation. Water for irrigation, therefore, should not be allocated uniformly through the district, but rather allocations should be based on the site-specific variables that control the ET rate. In addition, allowance should be made for the efficiency losses in the irrigation systems; these are now being evaluated.

Growers can influence one of the major variables controlling ET: the cover crop. Removing the cover crop by chemical means does not result in net economic returns in normal years as treatment costs are higher than water costs saved. Clean cultivation by discing is an economical solution for water conservation, but creates a definite soil erosion hazard. Use of rototillers, while more expensive than discing, apparently provides the best answer to soil and water conservation.

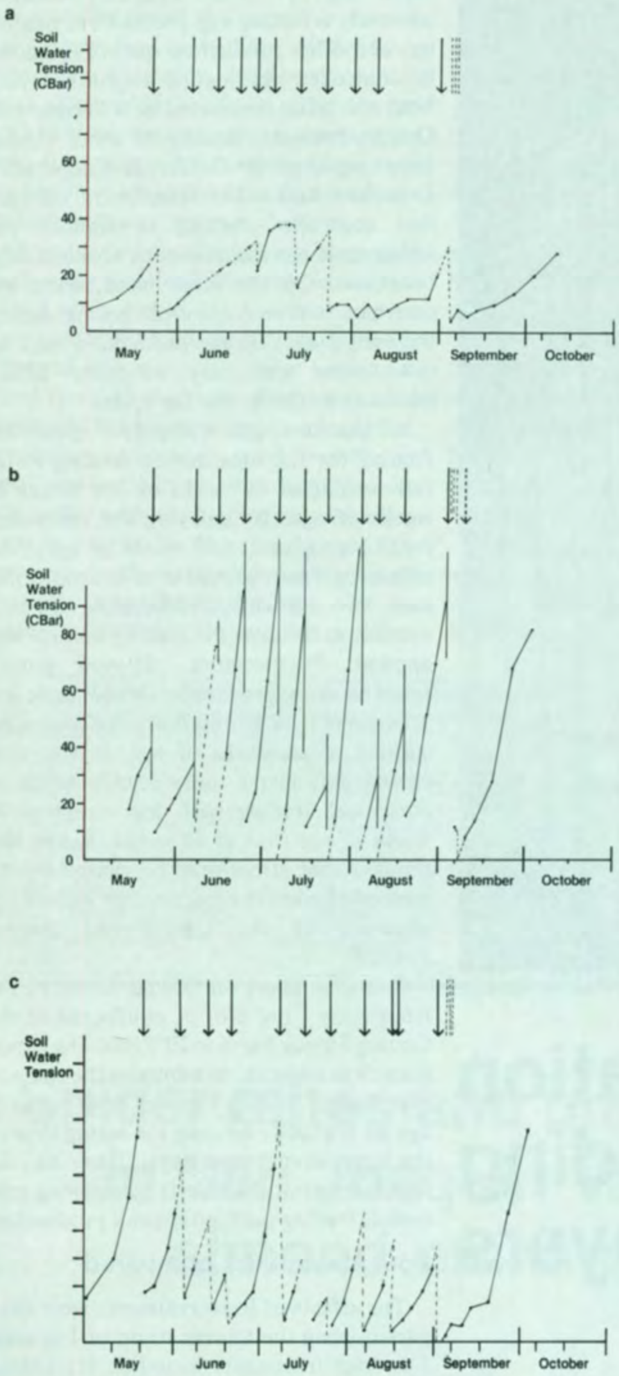


Figure 1. Soil water tension at 18-inch depth for a) 2.3 acre foot treatment without cover crop, b) 2.3 acre foot treatment with cover crop, c) 3.0 acre foot treatment with cover crop. Solid arrows indicate irrigations, dash arrows indicate rain.

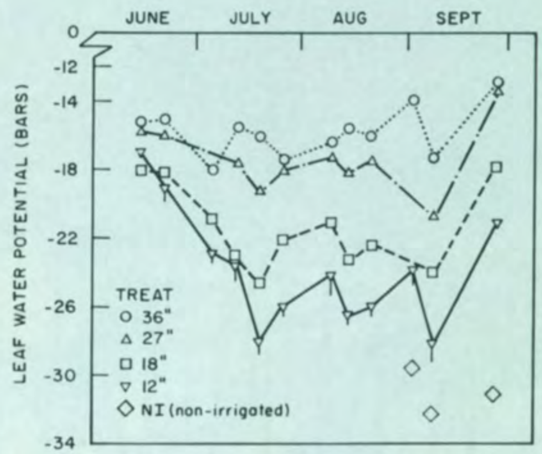


Figure 2. Seasonal changes in midday leaf water potential in an apple tree orchard.

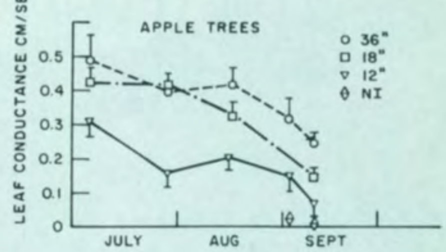


Figure 3. Seasonal changes in leaf conductance of apple trees.

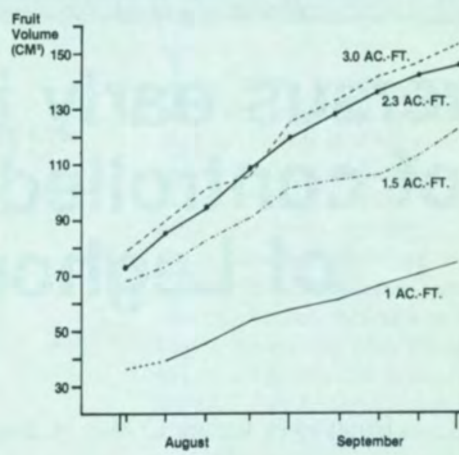


Figure 4. Increase in fruit volume in apple trees as a function of irrigation treatment.

Irrigating according to ET demand resulted in optimum tree performance and fruit size, while restricting the water supply well below ET had serious impacts on yields and particularly on fruit size, reducing marketability. The observed trends in soluble solids and fruit pressure, however, suggest that excessive irrigations may be detrimental to fruit quality of both pears and apples in the foothill environment. Also, excessive shoot growth resulting from over-irrigation could cause undesirable shading of fruiting wood and increased pruning costs.

The information presented here is being utilized in a joint program by EID, United States Bureau of Reclamation, and U.C. to provide irrigation scheduling services to more than 70 growers in El Dorado County, thereby increasing opportunities for optimizing water use and conservation in foothill orchards.

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