In early November 1980, almond trees on left were still being irrigated. Row on right had received no water since October 1 and was losing leaves, particularly near shoot tips.

Responses of young almond trees to late-season drought

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Water requirements of young almond orchards must be met throughout the season, despite the tree's reputation for drought resistance.

Almond trees are considered to be very tolerant of drought. It is not uncommon for almond trees to be subjected to substantial water stress during and after harvest without apparent significant detrimental effects on tree development and crop yields. As a result, irrigation during the latter part of the season is frequently neglected, not only in mature almond orchards but also in young plantations. The experiment reported here was designed to evaluate the possible detrimental impacts of late-season drought on young almond trees grown under drip irrigation.

The experiment was carried out at the Nickels soils laboratory, a 40-acre experimental orchard near Arbuckle in Colusa County, which was established by the late L.J. Nickels to conduct research and develop recommendations on soil and water management in northern California. The soil is an Arbuckle gravelly sandy loam with very little water-storage capacity. Two-year-old almond trees of the Nonpareil variety were selected in 1977 to conduct the experiment with three irrigation treatments and four replicated plots in a randomized block design. Each replicate plot had 14 trees.

Irrigation was cut off on September 1 for treatment A, on October 1 for treatment B, and was continued for the control treatment, C, until near leaf fall (mid-November). In 1979 all irrigation treatments were moved 10 days forward, because irrigation district maintenance made it difficult to maintain the water supply through mid-November. The trees were drip irrigated by two 1-gallon-per-hour microtube emitters in 1977 and 1978, and by four emitters per tree in 1979 and 1980. The drip irrigation schedule was based on daily readings from an evaporation pan in the orchard; the readings were multiplied by appropriate crop coefficients developed simultaneously by a parallel research project.

Measurements of tree water status as indi-

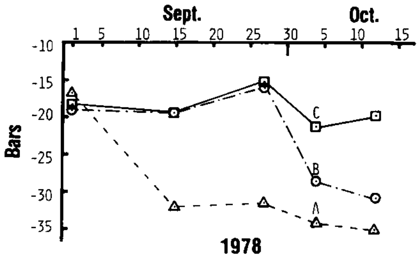

Fig. 1. Leaf water potential of almonds after irrigation cutoff on (A) September 1; (B) October 1; (C) mid-November (control).

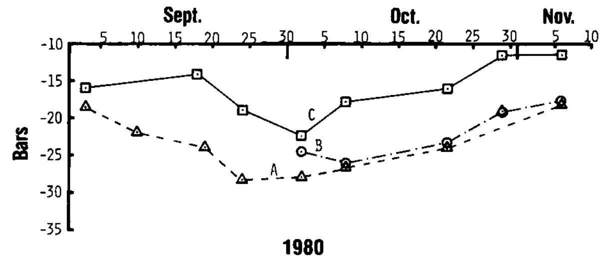

Fig. 2. Leaf water potential of almond trees after irrigation cutoff (A) on September 1; (B) on October 1; and (C) in mid-November, near leaf fall (control treatment).

cated by pressure chamber and leaf conductance measurements—an indicator of stomatal opening—were taken on selected trees in each treatment at frequent intervals after September 1 in each of the four years. Numbers reported here are averages of at least six measurements of midday leaf water potential and leaf conductance per treatment. Trunk growth was measured on each tree at selected times throughout the experiment; commercial nut yields were measured in 1979 and 1980.

Water status

The leaf water potential dropped substantially in treatments A and B only a few days after irrigation ended. In 1977 and in 1978 (fig. 1) when there were only two emitters per tree, leaf water potential dropped much more sharply than in 1980 when four emitters were used per tree (fig. 2). Use of four emitters probably built a reservoir of available water that prevented fast development of severe water stress. Leaf water potentials below -30 bars were frequently observed during 1977 and 1978, even in treatment B, but seldom occurred in 1979 and 1980.

The differences between the response of leaf water status during the first two and the last two years of the experiment illustrate the need for frequent irrigations under drip when very little available water is stored in the root zone reservoirs. In 1977 and 1978 the leaf water potential dropped more than 10 bars just five days after last irrigation. In 1979 and 1980, when the soil volume explored by roots increased because of larger tree size and increased number of emitters per tree, the levels of water stress that developed after irrigation was cut off were not as severe as in earlier years.

Reduced leaf water potential in treatments A and B brought about significant stomatal closure. Leaf conductance decreased as leaf water potential declined as a result of water stress (fig. 3). Since leaf conductance is an excellent indicator of photosynthetic activity under water stress, we could conclude that CO_2 assimilation was reduced in treatments A and B soon after the irrigation was cut off.

TABLE 1. Yearly Growth of Almond Trees Between September and November

Treatment	Increase in trunk cross-sectional area			
	1977	1978	1979	1980
	cm²	*cm²*	*cm²*	*cm²*
A	4.0	1.5	5.0	1.7
B	8.7	5.7	9.5	2.1
C	9.2	8.2	11.5	4.3

TABLE 2. Trunk Size of Almond Trees as Affected by Late-season Drought

Treatment	Trunk cross-sectional area on following dates			
	9/77	11/78	10/79	11/80
	cm²	*cm²*	*cm²*	*cm²*
A	26.8	70.7	121.0	160.0
B	25.2	78.1	133.7	178.1
C	26.3	81.2	138.6	185.0

TABLE 3. Yields of Almond Trees as Affected by Late-season Drought

Treatment	Yield of kernels per tree		
	1979	1980	Accumulated
	kg	*kg*	*kg*
A	1.74	2.39	4.13
B	1.75	2.67	4.42
C	2.00	2.96	4.96

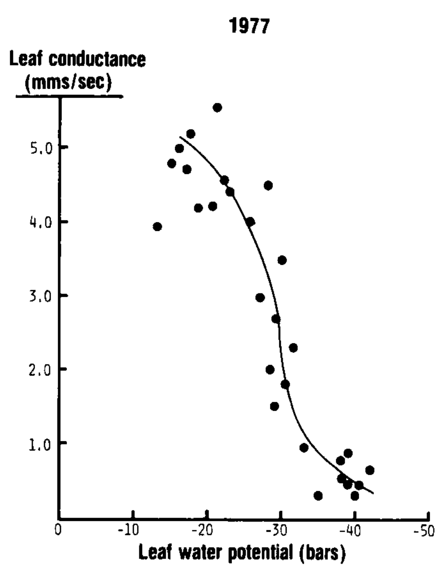

Fig. 3. Decline in leaf conductance with water stress in almond trees.

Tree growth and yields

The development of water stress after irrigation ended significantly affected tree growth. Trees in treatment A grew at less than half the rate of control treatment C (table 1). This reduction in rate of growth during the fall affected overall growth of the trees (table 2). After four years, cross-sectional areas of trees of treatment A were 16 percent less than those of the control trees. Similar differences were observed in canopy growth, indicating that the cumulative effects of water stress on treatments A had resulted in smaller trees.

In the last two seasons (fourth and fifth year of the orchard), the smaller tree size in treatment A resulted in reduced yields, as compared with the control (table 3). Over the first two years of production, the accumulated yield differences between treatments A and C amounted to 18 percent, which is similar in magnitude to the observed differences in trunk growth.

Conclusions

Late-season drought caused by early termination of irrigation in drip-irrigated, young almond trees resulted in water stress, which induced stomatal closure and early leaf senescence. This, in turn, substantially reduced tree growth and yield in the early stages of the orchard. (It should be noted that, in other soils with greater capacity for available moisture and under other irrigation methods, water stress may not occur as rapidly as in this orchard.) It appears that the water requirements of young almond orchards must be met throughout the season, despite the tree's reputation for drought resistance, if maximum growth and production are sought.

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