

# Orchard water use and soil characteristics

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Selection of an orchard floor management system is based on several considerations, often including its potential effect on water use, water infiltration, and soil compaction (table 1). Information on these factors has been limited, however, because many previous studies have compared only a few treatments or have produced site-specific recommendations that did not consider differences in soil characteristics or orchard management.

In 1984, we began a study to measure the effects of orchard floor management strategies on water use and soil characteristics, such as soil compaction, water penetration, and soil water-holding capacity. The two study orchards were both sprinkler-irrigated. Orchard A was newly planted on a loamy-sand soil. Orchard B, a mature orchard on a sandy-loam soil, had a tree canopy coverage exceeding 70% shading of the soil surface.

## Consumptive water use

We determined the crop water use of each treatment by measuring the change in soil water content between irrigations during each season. A neutron probe was used to measure water content at 9 to 120 inches of soil depth, and a soil sampling technique was used near the soil surface. Five neutron probe wells were arranged around each observation tree within each treatment. The water-use measurement periods depended on the irrigation schedule, but averaged 17 days throughout the growing season. We calculated daily water use for each measurement period by dividing the total amount of water used in the period by the number of days. Seasonal water use is the total of the use periods of a given season.

At both orchards, daily water use fluctuated in all treatments with variations in environmental demand, indicated by reference evapotranspiration (shown as ETo in fig. 1). Each year within each orchard, resident vegetation (weeds) and perennial clover were similar in seasonal water use, and they used the most water among the treatments (table 2). Residual herbicide and chemical mowing treatments, also similar to one another in consumption, used less water than resident vegetation and clover.

During the cover crop establishment year at each orchard, clover showed less early-season water use than did resident vegetation. By the end of the season, however, both had consumed similar volumes of water on a seasonal basis. In the following years, no significant differences were found between these two treatments at any time.

Bromegrass was an interesting exception to the behavior of the other cover crops. Bromegrass, a winter annual, had a water use pattern similar to that of the other cover treatments early in the season. As the crop matured, daily water use more closely re-

sembled that of the residual herbicide or chemical mowing treatments.

Large quantities of bromegrass residue were produced in the mature orchard during 1985, in part because of adequate soil moisture and an infrequent mowing schedule. After it matured and was mowed, bromegrass had significantly lower daily water use than did all other treatments (fig. 1). We assume these differences are due to the mulch remaining on the soil surface after mowing, apparently reducing the water lost through surface evaporation. By the end of the measurement season, we found

TABLE 1. Effects of orchard floor management systems on soil-related characteristics\*

Consideration	Tillage	Cover crop	Resid. herb.	Chem. mow
Power and machine requirements	D	A	A	A
Erosion potential	D	A	D	A
Frost hazard	M	M	A	A
Ease of harvest	A	M	A	M
Root zone expansion	D	A?	A	A?
Water use	A?	M	A	A
Soil compaction	D	A	D	A
Water penetration	?	A?	D	?
Winter access	M	A	D	A

\* A = advantage. D = disadvantage. M = management-dependent. ? = unknown.

TABLE 2. Seasonal water use in treatments at orchards A and B

Treatment	Seasonal water use*			
	Seasonal (inches)	Per-cent	Seasonal (inches)	Per-cent
	1984 4/7 - 8/18		1986 4/29 - 7/29	
<b>ORCHARD A</b>				
Resident vegetation	18.6 a	136	24.9 b	124
Clover	17.6 ab	129	25.9 a	129
Bromegrass	16.1 b	118	21.7 c	108
Residual herbicide	13.7 c	100	20.1 d	100
	1985 4/10 - 10/3		1986 4/22 - 8/22	
<b>ORCHARD B</b>				
Resident vegetation	40.8 a	123	31.9 a	117
Clover	41.0 a	123	30.8 a	114
Bromegrass	32.1 b	96	26.8 b	99
Residual herbicide	33.2 b	100	27.1 b	100
Chemical mow	33.9 b	102	27.0 b	99

NOTE: Percentage comparisons are relative to residual herbicide.

\* Values within a column followed by the same letter are not significantly different at P<0.05 level using Duncan's multiple range mean separation technique.



Neutron probe access tubes in the herbicide-treated strips down the tree row measure soil water content in a Salina strawberry clover planting.

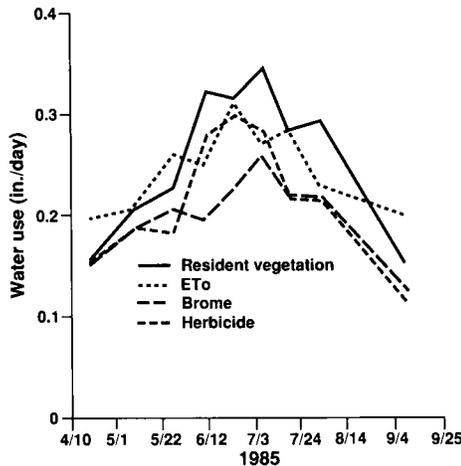


Fig. 1. Daily water use in four treatments in 1985 season, orchard B. Chemical mowing dates were 4/16, 6/18, 7/19, 8/14; mechanical mowing, 3/5, 4/24, 5/30, 6/13, 7/18, 8/6, 8/28.

no significant differences between brome-grass and either the residual herbicide or chemically mowed treatments at orchard B.

Because of low ground-surface shading in the developing orchard, there were greater differences in water use between treatments. As tree crop water consumption increased with orchard maturity, the influence of the cover crop water use decreased. The difference in water use between resident vegetation or clover and the residual herbicide was greater in 1984 than in 1986, 35.8% and 23.9%, respectively, in orchard A.

### Soil compaction

To measure soil compaction, we used an instrument to test soil strength—a totalizing soil cone penetrometer. The greater the strength, the greater the compaction. The instrument was inserted to a soil depth of 5 inches at 6-inch intervals between tree rows within each treatment. We also measured soil bulk densities, a second method of determining soil compaction.

Both methods gave similar results for treatment comparisons. Soil penetrometer values varied from year to year because of field conditions, such as soil moisture, at the

time of reading. This method showed a relative change, which may be of greatest value in comparing treatment effects. Results are presented as a comparison with the clover treatment in both orchards.

Orchard A had significantly (.05 level) more compaction in the residual herbicide treatment than in any of the other treatments in 1985, 1986, and 1987 (fig. 2). This is a change from the initial data taken the year the orchard was established (1984), when no significant differences between treatments existed. In orchard B, soil strength increased in the herbicide treatment during 1986 and 1987, while strength in the other treatments remained constant or decreased slightly. Soil strength in the residual herbi-

cide treatment was significantly higher (.05 level) than in all other treatments in 1987 (fig. 2).

### Water penetration/ holding capacity

Water penetration was indicated by the amount of time required for surface ponding to occur during an irrigation. Since the irrigation systems at both orchards applied water at rates lower than the ability of the soil to take in water over the term of the irrigation, there were no differences.

We evaluated soil-water holding capacity in each treatment at both sites, using a laboratory procedure to test soil samples collected from the orchards. There were no significant differences during the study.

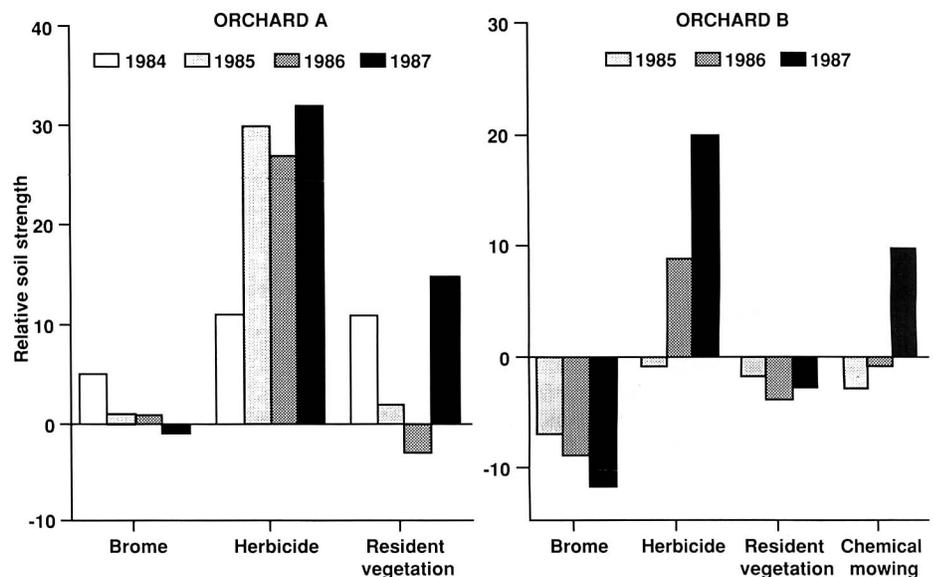


Fig. 2. Compaction, shown by average soil strength in each treatment relative to the clover treatment, was highest in the residual herbicide treatment after the first year in both orchards.

## Conclusion

After three years of observation in two almond orchards of different maturities and soil types, significant differences in water consumption were found among the five treatments. In both orchards, total water consumption (used by plants and lost to evaporation) was less in the residual herbicide and chemically mowed treatments than in clover or resident vegetation treatments, on both a daily and a seasonal basis.

The differences amounted to a two-year average of 20.5% for the mature orchard (orchard B). Bromegrass, when managed to create a mulch (orchard B in 1985), resulted in greater early-season water use but reduced water use at mid-season; total seasonal water use was similar to that of residual herbicide and chemical mowing.

In orchard A, resident vegetation used 35% more water than did the residual herbicide treatment in the establishment year and 23.9% more in 1986. Bromegrass was

intermediate in water use, varying each year mainly because of stand quality and mowing frequency.

Although the orchards represented different soil types and maturities, they both showed similar trends in water use by treatment. The treatment differential was magnified in the younger orchard, suggesting that the effect of orchard floor management systems on water use may be greatest in young orchards. The differential declined with orchard maturity, probably because of increased shading, competitive water use, and longer times between irrigations.

In evaluating effects of orchard floor management on soil characteristics, we detected a significant increase in surface soil compaction in the residual herbicide treatments in both orchards. No differences were found in soil-water holding capacity or water intake rate. Since changes in these soil physical characteristics are viewed as cumulative and the rate of change depends

on orchard operations, further increases in soil strength in the residual herbicides may occur.

Selection of an orchard floor system should be based on the soil and management limitations of the orchard. If water supplies are limited, a system using residual herbicides, chemical mowing, or bromegrass would be appropriate. If water infiltration rates are poor, a different solution would be required. Either chemical mowing or bromegrass offers a combination of benefits in reducing soil compaction as well as minimizing seasonal water use.

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# Almond orchard floor management costs

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In selecting an orchard floor management system it is necessary to evaluate the costs of developing and maintaining the systems under consideration. We estimated sample costs for the five systems studied as treatments of the centers between the tree rows—Blando bromegrass, Salina strawberry clover, resident vegetation, residual herbicide, and chemical mow, as described in the introductory article. These costs were also compared with costs of disking the centers between the tree rows and disking and mowing the centers, two traditional vegetation management practices in California not included in the field trials.

Annual costs of managing the orchard floor for each alternative were estimated based on the results of the trials. The actual costs of the trials could not be used because of the small size of each plot relative to a commercial orchard. In this report, we discuss the differences in orchard floor cultural practices, irrigation, and related costs. Cultural costs such as pruning, pollination, and brush removal are not included, because they remain the same regardless of floor management regime and are not really part of the floor management system.

## Establishment and maintenance

Costs of managing the two planted cover crops, Salina strawberry clover, and Blando bromegrass, include seedbed preparation, seed planting, and extra fertilizer. The bromegrass was fertilized with nitrogen every year; the clover, a perennial, was fertilized with phosphorus plus some nitrogen only in the year it was planted. Costs in the establishment year were \$74 per acre for bromegrass and \$59 for clover (table 1).

In all of the systems, weed control along the tree rows with a pre-emergence herbicide application in December or January and a contact spray in May or June cost about \$29 per acre per year (table 2). The strategies all differed in the way vegetation was controlled between the tree rows or along the middles. The nontillage systems all relied on mowing.

The planted covers were mowed seven times at a cost of about \$31 per acre per year: twice before frost, once after seedheads formed, and four times during the season. Annual bromegrass fertilization cost \$11.

The costs of establishing the planted covers (table 1) were allocated on an annual basis over the life of the orchard and are

included in the annual cost estimates (table 2). Including the amortized establishment costs (\$5 per year for clover and \$7 for bromegrass) makes direct comparisons possible between the planted covers and the other regimes.

The resident vegetation was mowed eight times, once more than the planted cover crops, for a total cost of \$35 per acre per year. This compares with about \$39 for chemical mowing of the resident vegetation in the middles. Four applications of glyphosate were included in the chemical-mow cost estimates—two in winter, one in summer, and one to clean up the plants before harvest.

A combination of mowing and cultivating the resident vegetation cuts the number of mowings from eight to four and adds three cultivations. An alternative is to cultivate five times instead of mowing. Under either management regime, the orchard floor also must be rolled in preparation for harvest and sprayed with herbicide. Preparation for harvest adds two more operations, making nine for the mowing and cultivating option totaling \$48, and seven for the cultivated orchard totaling \$42.