Project No. 93-H5 - Effects of Water Supply and Irrigation Strategies on Almonds

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Objectives:

1. Determine the relationship between seasonal consumptive water use and the growth yield and quality of almonds.
2. Evaluate irrigation strategies to maximize plant performance given limited water supply on a short term and sustained basis.
3. Further define crop coefficients (K_C) to be used for advanced irrigation scheduling techniques.

Results:

Almonds are known for their dependency on irrigation water to maintain acceptable and consistent yields of a quality crop. They are, however, known to be tolerant of water deficits. The questions at hand are:

1. Can almond orchards use less than their full water requirement and still maintain production? What are the effects on crop quality?
2. If so, when can the water deficits safely occur?

Since the climatic drought as well as a competitive use drought could limit water availability, an additional question is posed.

3. If an orchard does not have a full water supply available, how should an orchardist supply the trees to minimize the impact of water deficits?

In 1990, an experiment was started to attempt to answer these questions. The experimental conditions were:

irrigation system:	full coverage sprinkler	experimental area:	10 acres
soil type:	deep, sandy loam	location:	San Joaquin Delta College Farm, Manteca, CA
trees:	Nonpareil, Price, Peerless 12 yrs. old in 1990 uniform stand	rootstock:	Nemaguard

Imposed treatments include one treatment which provides water for full consumptive use (100% ET) and four treatments which provide for less than full water use (70% and 50% ET) on a seasonal basis while imposing water deficits primarily during either midseason or postharvest. A sixth treatment (Pii or plant-indicated irrigation) utilizes leaf water potential as an indicator of plant water status for scheduling irrigations after June 15, rather than using set values of water use and static times of deficit imposition. Treatments were imposed beginning in the 1990 season and continued through the 1993 season. All results presented in this paper are from Nonpareil variety.

Review of 1990 Results

As a result of the first year of treatments, no significant differences in yield or other measured nut quality parameters were observed. Hull split, however, progressed at a slower rate, ultimately resulting in significantly more hull tights in Treatment 3 (50% ET) and Treatment 5 (70% ET)--both treatments with stress occurring midseason--when compared to their postharvest stress counter-parts (Treatment 2 and Treatment 4).

Review of 1991 Results

The full water use treatment (Treatment 1) produced a significantly greater yield compared to other treatments with the single exception of the plant indicated irrigation treatment (Treatment 6) which also exhibited a high yield. Fifty percent hull tights occurred in Treatment 5 (midseason deficit) while all other strategies resulted in less than 1.5% hull tights.

Spreading the deficit over both midseason and postharvest (Treatment 4, 50% ET), with the same volume of water was seen as a preferred strategy when compared to midseason deficit only. Hull tights were significantly reduced in Treatments 2 and 3 by the virtue of irrigation near the beginning of hull split. No significant differences were found in other measured quality parameters or pruning weights. There was no significant difference in bloom or nut set.

Review of 1992 Results

Again, as in 1991, the full water use treatment (Treatment 1) and the plant indicated irrigation treatment (Treatment 6) produced significantly higher yields than all other treatments.

No significant differences were found in nut quality for the 1992 harvest. Incidence of worms, mold, ant damage, shrivels, and doubles were similar throughout all treatments.

Yields were down in 1992 in comparison with 1990 and 1991, as were those of the entire industry. Yields were reduced in less than full water use treatments with the exception of Treatment 6. The lack of differences between the reduced ET strategies may be a result of the warm spring and moderate preharvest conditions, culminating in an early harvest and minimizing the physiological ramifications of reduced water supply. These conditions may also explain the lack of hull tights in any of the treatments. As evidence, pre-dawn leaf measurements at beginning of hull split were only -12 bars when compared to -20.5 bars in 1991.

Review of 1993 Results

As in the past two crop seasons, the full water treatment (Treatment 1) was significantly higher in yield than all other treatments with the exception of plant indicated irrigation (Treatment 6) (Table 1). Hull split occurred slightly earlier in the treatments with less than full water supply and progressed at a more rapid rate (Table 2). Ultimately, all treatments achieved full hull split by Aug. 2, 1993. In an attempt to cause the occurrence of full hull split, two replications of Treatment 5 (50% midseason deficit) were irrigated at hull split with water previously withheld. The result was full hull split in the replications receiving one inch water at hull split while 35% of the nuts did not split and remained as hull tights in the deprived replications.

Table 1.

	1993			
Treatment	Percent Seasonal Use	Consumptive Water Use (in)	Average Yield (lbs of kernels/acre)	Relative Yield % of Treatment 1
1 (100% use)	100	37.2	3480 A *	100
2 (70% use) (postharvest deficit)	71	26.4	2800 B	80
3 (70% use) (midseason deficit)	69	25.9	2239 C	64
4 (50% use) (midseason and postharvest deficit)	52	19.3	2638 BC	76
5 (50% use) (midseason deficit)	51	19.0	2459 BC	70
6 (Pii)	66	24.6	2964 AB	85
P-value			0.0050	

* Common letters among means within runs denote no significant difference at $P \leq 0.10$.

Combined Years Results

Combining data from each year makes for easy comparison of the effects of irrigation strategy on a sustained basis. The yield in meats pounds per acre was found to be significantly different due to treatment--both irrigation level and timing strategy. Table 3 shows the consumptive water use and yield.

The full water use treatment resulted in the highest combined yields, although it was not significantly different from that of the plant indicated irrigation (Treatment 6). On a combined yield basis, no significant differences were found in irrigation strategy between the two treatments, those (T2 and T5) receiving near 70% of full water use. Treatments 4 and 5 compared the viability of two irrigation strategies for supplying water at the 50% ET level. Treatment 4 supplied water preharvest with no postharvest irrigation. Treatment 5 withheld water preharvest and supplied that water postharvest. Supplying water preharvest (Treatment 4) was found to be superior in that yield was significantly higher and the amount of hull tights was reduced.

What factor influences the meat yield? A correlation was performed to find the relative influence of number of nuts per tree, kernel weight and pruning weights on meat yield. Each factor was found to have a significant impact on yield. Further analysis indicates the strongest influence is the number of nuts per tree. The more nuts per tree result in more yield. Nut number per tree explains 81.7% of the change in meat yield while nut size explains only 6.3%.

These results indicate water deficits effect almond like other crops, in that vegetative growth is reduced. This reduction in mature trees decreased the number of possible fruiting sites. Long term, this results in fewer nuts per tree. Water stress, however, can cause reduction in nut size. To test the strength of these assumptions, a model was developed using nut number, nut size and pruning weights to predict yield. Using data from this experiment, the results are shown in Figure 1. The fit of field data (points along the line) to the predicted values (solid line) is extremely good ($r^2 = 0.993$).

Bloom and nut set were measured in 1991, 1992, and 1993 measured as flowers or nuts set per 60 cm branch. Significant differences by treatment were found in only 1991 in bloom, although set that year was unaffected. In all other years and as combined years' results, neither bloom nor set was significantly affected by treatment.

Pruning weights were measured in 1991, 1992, and 1993. No significant differences were found in 1991, although they were significant in 1992 with the full water treatment (Treatment 1) exceeding all other treatments (Table 4).

Table 2.

Treatment	1993					
	Hull Splits				Hull Tights %	Pruning Wt/tree #/acre
	7/22	7/26	7/29	8/2		
1 (100% use)	9.8 C	71.4 C	83.6	100	4.3	28.6 A**
2 (70% use) (postharvest deficit)	14.0 C	85.3 B	95.5	100	0.6	14.5 B
3 (70% use) (midseason deficit)	53.8 A	99.5 A	100	100	0.9	13.9 B
4 (50% use) (midseason and postharvest deficit)	25.8 BC	99.8 A	100	100	0.4	23.0 AB
5 (50% use) (midseason deficit)	29.8 ABC	92.0AB	98.8	100	16.5*	14.4 B
6 (Pii)	48.3 AB	89.0 AB	97.75	100	0	18.6 AB
P-value C.V.	0.0109		0.0971	0.2834	0.3337 ns	0.0486

* 2 reps given 1 inch water at hull split
2 reps given 1 inch water before hull split
hull split observed on treatment receiving water at hull split
**Common letters among means within runs denote no significant difference at $P \leq 0.05$.

Table 3.

Treatment	Combined Years, 1990-93			
	Percent Seasonal Use	Consumptive Water Use (in)	Average Yield (lbs of kernels/acre)	Relative Yield % of Treatment 1
1 (100% use)	100	37.4	3358 A	100
2 (70% use) (postharvest deficit)	72	26.9	2755 BC	82
3 (70% use) (midseason deficit)	66	24.7	2572 C	77
4 (50% use) (midseason and postharvest deficit)	52	19.8	2841 B	85
5 (50% use) (midseason deficit)	50	18.5	2623 C	78
6 (Pii)	66	24.7	3136 A	93
P-value			0.0054	

* Common letters among means within runs denote no significant difference at $P \leq 0.10$.

Table 4.

Treatment	Combined Years, 1990-93				
	Nuts/ Tree	Kernel Wt	Pruning Wt lbs/tree	Green Tip %	Hull Tights Wt % of Meat Yield
1 (100% use)	15.8 AB	1.28 A	38.8 A	3.3 AB	0.7* B
2 (70% use) (postharvest deficit)	13.7 D	1.22 B	25.6 C	3.2 AB	0.3 B
3 (70% use) (midseason deficit)	14.1 CD	1.09 DE	27.1 C	4.2 A	4.8 B
4 (50% use) (midseason and postharvest deficit)	15.2 ABC	1.12 D	32.2 ABC	2.0 B	0.5 B
5 (50% use) (midseason deficit)	14.6 BCD	1.08 E	27.7 BC	4.6 A	23.1 A
6 (Pii)	16.3 A	1.17 C	34.4 AB	4.1 A	0.5 B
P-value	0.0012	0.0	0.003	0.039	0.0

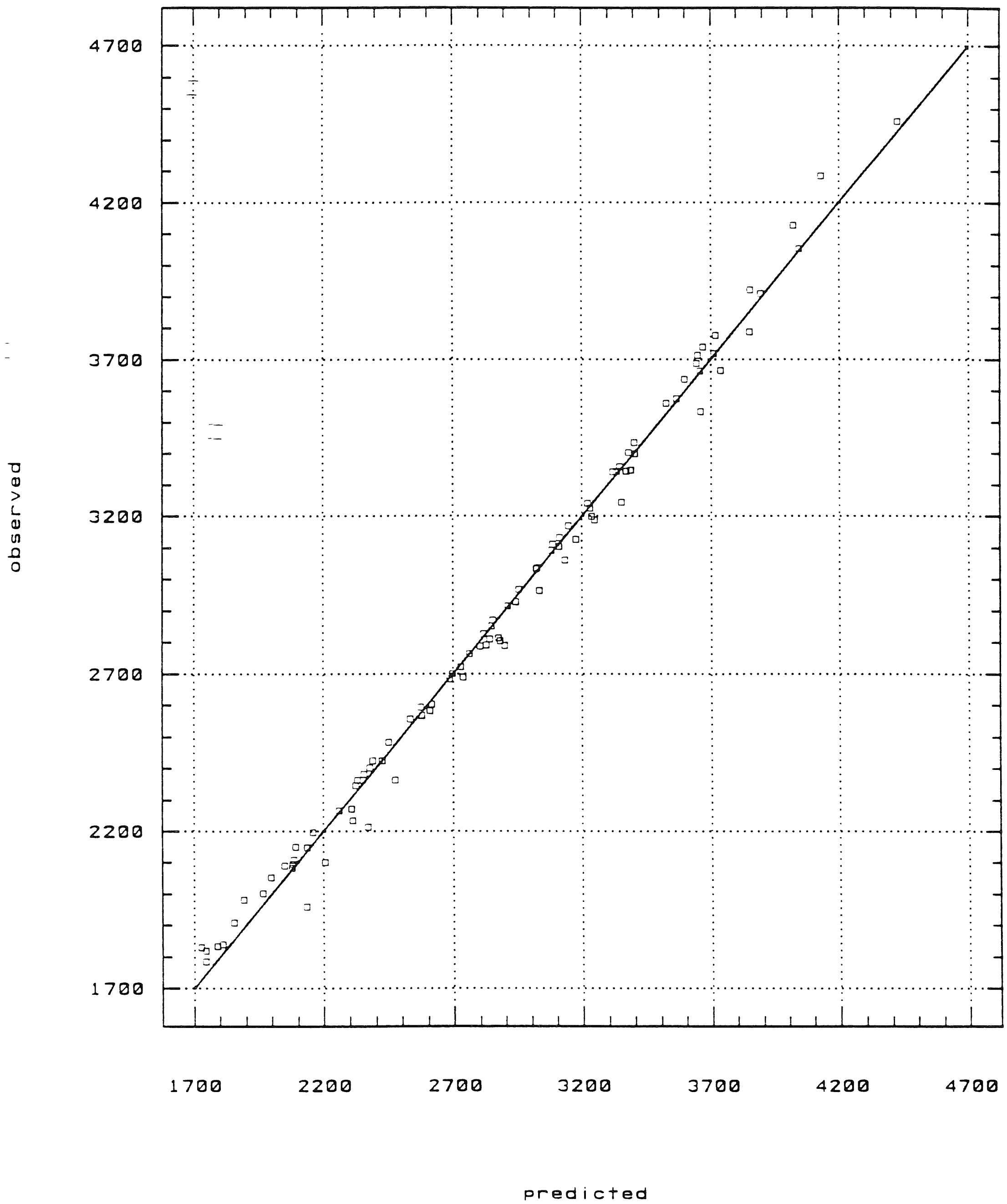
Summary

After three years of imposed irrigation treatments varying the amount of water and timing of its use, we found significant differences in yield, progression of hull split, hull tights and vegetative growth (pruning weights). No differences were found in other quality parameters. Yield differences are primarily a result of fewer nuts per tree as well as a small component due to decreased nut numbers. In high set years, nut number is of greatest importance while in low set years, kernel size takes on increased importance. The reduced vegetative growth occurring in the less than full water use treatments also contributes to reduced nut load by the virtue of having less fruitwood.

One of the most encouraging treatments is the plant indicated irrigation (Pii, Treatment 6). Over the four-year duration of the experiment, this strategy has resulted in 93% of the yield of the full water treatment while using an average of 66% of the water. Of concern is the slight lack of vegetative growth observed, which may lead to a long term production decline.

This method of using a pre-dawn leaf water potential threshold of -12 bars to schedule irrigation looks promising as a tool to follow an irrigation strategy to minimize the effect of a reduced water supply.

Figure 1.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