Final Report: Project 99-KS-o1
Reducing shaker Barking Injury

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Introduction:

The long range goal of this research is to reduce the problem of shaker injury in almond orchards. It has long been believed that irrigation close to harvest is a major factor contributing to shaker injury, but there is little objective evidence to support this claim. Since water stress can have many important effects on almond production, it is necessary to consider both the positive and the negative impacts of water management to determine whether irrigation cutoff prior to harvest is necessary or even desirable as an orchard management practice.

Objectives:

This was the first of a planned 3 year study with two primary objectives: 1) to test irrigation strategies that combine hull rot and irrigation cutoff treatments for evidence of any consistent effects on shaker injury or tree productivity and 2) to develop a reliable diagnostic measurement of bark strength in almonds that can be used to estimate the likelihood of tree damage during shaking.

Materials and Methods:

A 24 acre test plot was established in a 7 year-old, highly productive Nonpareil/Butte/Sonora orchard at Paramount Farms near Shafter, CA, with 6 acres each of 4 irrigation treatments (Table 1).

Table 1. Description of each of the four irrigation treatments.

Treatment designation	Description
Blue	Full irrigation all season, pre-harvest irrigation cutoff of 2 1/2 days (60h)
White	Full irrigation all season, pre-harvest irrigation cutoff of 7 days (normal grower practice)
Red	Irrigation cutback during hull split to control hull rot, pre-harvest irrigation cutoff of 2 1/2 days (60h)
Green	Irrigation cutback during hull split to control hull rot, pre-harvest irrigation cutoff of 7 days

The study was conducted in a randomized complete block design, with two blocks. Experimental plots were 16 rows X 15 trees, and data was taken from 1 Nonpareil tree in the center of each of 4 quadrents in each plot, giving 4 subsamples per plot. Applied water was measured using water meters and tree water stress was monitored with weekly measurements of midday stem water potential. At harvest on 9/1/99, a total of 8 test Nonpareil trees in each treatment were shaken with a commercial shaker (FMC) for a long time (15 seconds) at a high clamping pressure (2,000 psi) in order to see if severe shaking would cause barking injury and if differences between the treatments could be detected. The day before harvest, the bark strength of half of these trees was also measured with a hand device. Nut splitting, hull rot strikes and a number of other harvest paramenters (kernel weight, percent moisture, sticktights, etc.) were measured on each of the 4 subsample trees per plot. Water stress during hull split also caused some inner canopy leaves to drop, and this effect was measured by measuring the dry weight of leaf litter from a standard area of ground below each of the subsampled trees.

A laser displacement device and a single axis accelerometer device were connected to a datalogger and were used to measure the motion which occurred during shaking both on the shaker and on the tree. These tests were done using a mulberry tree at a site near Chico, CA.

Results and Discussion:

Measurements of midday stem water potential showed that Red and Green treatments were

moderately stressed during hull split, compared to the Blue and White treatments, which exhibited values equivalent to the fully irrigated reference value during this time (Fig. 1). At harvest the Blue and Red treatments also exhibited values equivalent to the fully irrigated reference value. This is an important result, because it means that the Blue treatment was maintained at a fully irrigated level up to and including harvest. Water meters were not operational until early July, but showed clear treatment differences during the hull split period (Fig. 2). It is interesting to note that the water applied to the Blue and White treatments was above the calculated ET_c, whereas that applied to the Red and Green treatments was very close to ET_c (Fig. 2). This indicates that applying full ET_c may not eliminate the possibility of tree water stress in almond.

None of the severely shaken trees in any treatment showed any loss of bark, but careful inspection of the trunks showed that some of these trees did exhibit small amounts of damage, and this damage was rated by measuring the area of bark that was loosened (Table 2). Some of the damaged trees also showed a small "wet spot" at the site of damage. The results of the bark strength measurements and the severe shaking test showed that there were no significant differences among the irrigation treatments (Table 2)

Table 2. Pre-harvest bark strength and observed injury due to shaking selected trees for a long time (15s) at a high clamping pressure (2,000 psi).

Pre-harvest bark strength		Damage from severe shaking	
Treatment	Strength (psi)	Treatment	Damaged area (in^2)
Red	76 a	White	2.6 a
Blue	62 a	Red	1.3 a
Green	60 a	Blue	1.0 a
White	60 a	Green	0.8 a

Note: values followed by the same letter are not statistically different at the 5% level (DNMRT).

These results are consistent with previous findings that there is no apparent effect of irrigation on bark strength, and this was the same for barking damage due to severe shaking.

The rest of the trees in the plot were harvested normally, and damage was evaluated by counting the number of trees with injury in the center row of each plot. There were a total of 4 rows scored, each with 60 trees, and each row was harvested by a different shaker and operator, but all operators used the same model and manufacturer of shaker. Damage only occurred on trees in one row (row #13), indicating that the problem was due to either mechanical or operator error, but the damage was also very light, and there was no apparent relation of irrigation treatment to the damage (Table 3).

Table 3. Damage in Row #13 from normal shaker harvest

Treatment	Number of trees damaged
Red	8
Green	5
Blue	1
White	1 (replant)

Since the Blue treatment was the most heavily irrigated of all the treatments, this data supports the conclusion that irrigation close to harvest does not increase tree susceptibility to shaker injury. We should become more confident of this conclusion after these results have been repeated in different years.

Even though irrigation did not influence shaker injury, it did have an influence on a number of other important factors. It was expected that stress during the hull split period would reduce hull rot strikes, which did occur, in addition to a parallel reduction in sticktights (Table 4).

Table 4. Hull rot strikes and sticktight nuts (nuts that were not removed during shaking).

Hull Rot Strikes		Sticktight nuts	
Treatment	# of strikes per tree	Treatment	# of nuts per tree
Blue	642 a	Blue	128 a
White	523 ab	White	110 ab
Green	214 bc	Green	73 ab
Red	82 c	Red	45 b

The two treatments (Red and Green) that experienced water stress during the hull split period had less hull rot strikes and less stiktight nuts than the treatments that were fully irrigated during this time. Water stress also caused a detectible level of defoliation and parallel increase in hull split, although the variation in the hull split data precluded a statistical separation between treatments (Table 5).

Table 5. Defoliation and nut split effects of the 4 treatments.

Dropped leaf litter on 8/13		Percent split nuts on 8/13	
Treatment	Weight of leaf litter (g)	Treatment	% split nuts
Red	33.4 a	Red	100 a
Green	24.6 b	Green	100 a
White	13.0 c	White	82 a
Blue	9.4 c	Blue	79 a

These data indicate that managed water stress may have a number of beneficial effects on the nuts (increasing split, reducing hull rot and stick tights) and some negative effects on the plant (defoliation). Hence, further research will be needed to determine the optimal balance between these factors, in addition to any long term effects that may be found. The trees were shaken on 9/1/99, but on two dates prior to this, percent moisture of the nuts was determined. On 8/31 there was a signiificant reduction in nut percent moisture by water stress during the hull split period, and at harvest there was no significant effect on kernel weight, although the ranking of the treatments for kernel weight was the same as that for percent moisture (Table 6).

Table 6. Treatment effects on pre-harvest nut percent moisture on two dates and kernel weight at pickup.

Nut percent moisture (8/13)		Nut percent moisture (8/31)		Kernel weight at pickup (9/9)	
Treatment	% Moisture	Treatment	% Moisture	Treatment	Weight (g)
Blue	75 a	Blue	43 a	Blue	4.63 a
White	74 a	White	43 a	White	4.38 a
Green	74 a	Green	16 b	Green	4.10 a
Red	69 b	Red	10 b	Red	4.02 a

These irrigation effects on the nuts are very consistent with the other effects that we have described, with water stress apparently leading to earlier splitting, more rapid drying and less susceptibility to hull rot, but also a slight reduction in kernel size. In all cases, the two treatments (Red and Green) that experienced stress during the hull split period contrasted with the two treatments (Blue and White) that were well irrigated during this period, regardless of irrigation cutoff. These results indicate that water management can be an important tool for controlling disease and for manipulating nut harvest in almonds. If the lack of any irrigation effect on bark strength and shaker injury is confirmed in future years, then the use of this tool will be substantially simplified.

We continued to refine the method used to measure bark strength in almonds, and under controlled laboratory conditions, found that when faster test speeds were used, higher values of bark strength were measured. This is an important result because the forces applied to the trunk during shaking change very rapidly, and it may be necessary to match this speed in order to obtain test results that reliably reflect the resistance of the bark to shaker injury. Instrumentation to actually measure the forces applied to the trunk during shaking were developed and field tested, and these showed that there may be substantial up-and-down ("Z"

direction) movement both on the shaker and on the tree (Fig. 3, top).

This may be a very important result because presumably an up-and-down movement would cause significant stress on the bark and possibly the root system, without any benifit to nut removal. A mathematical analysis of this data showed that there was significant power at high frequencies (Fig. 3, bottom), but the maximum frequency detectible by the datalogger used was 20 Hz, and so a faster data collection system will be required for reliable measurements to be made in the future. Our finding that tree damage was restricted to one row of our test plot indicates that there may be important differences between different shakers or shaker operators. We should emphasize however, that all the operators at our site were experienced, so that major differences between operators would not be expected. Measuring the forces that are applied by the shaker during the shaking process will be an important step in identifying the source of these differences in shaker injury.