Drought Survival Strategies for Established Almond Orchards on Shallow Soil

Project No.: **12-HORT8-Shackel**

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Objectives:

- Determine the first through third year carryover effects on almond production and tree survival of partial irrigation (approximately 5" and 10" of water) applied to both kaolin (Surround) sprayed trees and non-sprayed trees (control), compared with fully irrigated control trees.
- Determine the first through third year carryover effects on almond production and tree survival of either reducing the tree canopy by 50% or treating it with kaolin (Surround) spray under non-irrigated (rain fed) conditions.
- Relate shoot growth and spur survival patterns in the different treatments to the carryover effects observed.

Interpretive Summary:

This single year drought study was performed on mature (19 years old in 2009); single line drip irrigated Nonpareil almonds at the Nickels experiment station in Arbuckle, CA. Previous research at this site has documented that these trees have a relatively shallow (3') active root system for the purposes of irrigation scheduling, and hence we expected substantial tree dieback/death when trees were non-irrigated (2" of in-season rain) in 2009. In addition to a non-irrigated and a standard irrigated (31") treatment, two partial irrigation treatments (3.6" and 7.2," using the same irrigation schedule as for the standard irrigation treatment) were applied to simulate reasonable grower 'survival strategies' when faced with a drought and reduced water supplies. Some of the non- and partially irrigated trees were also sprayed with kaolin (Surround) to reflect sunlight, with an additional 50% canopy reduction treatment for some trees of the non-irrigated treatment, to simulate alternative grower practices hypothesized to improve tree survival under drought. For some trees in 2009, the level of drought stress (midday stem water potential, SWP) was severe, with one non-irrigated tree reaching more

than -60 bars and entirely defoliating by late July 2009, but ***all trees survived***. Soil water uptake was found to occur to the deepest depth measured (10’), and based on measured rainfall and estimates of soil water depletion, we tentatively conclude that almonds may survive on as little as 7.6” of water during the growing season. Tree productivity (nutmeat yield) was reduced by drought both in the drought year as well as in the subsequent year, with the degree of reduction depending on the level of SWP experienced by the tree. For severe stress (SWP below -40 bars) yield was reduced by about 50% in the drought year and 90% in the subsequent year, but yield recovered back to control levels for this as for the other levels of stress in the following two years. Less severe stress was associated with less severe effects on yield, and hence any level of irrigation during a drought year was found to be beneficial for tree health and yield. Canopy treatments such as kaolin spraying or severe pruning gave no overall yield benefit, and no apparent benefit to tree health.

Materials and Methods:

The trees of this study are located at the Nickels estate (Arbuckle, CA), and are the surface (single line) drip irrigated plots of the Marine Avenue irrigation experiment. A total of 5 replicate plots consisting of 6 rows X 11 trees were established, with 2 of the rows being Nonpareil, bordered on each side by one of three other varieties (Butte, Carmel, Monterey) serving as guards. Each plot consisted of 8 treatments as described in **Table 1**.

Table 1. Treatments designed for application in the simulated drought year (2009).

Irrigation Treatment	Canopy Modification
0” (rain fed)	None
	50% reduction once SWP Reaches -15 bars
	50% reduction + Kaolin spray
5" in-season	None
	Kaolin spray
10" in-season	None
	Kaolin spray
Control (100% ETc, ≅40")	None

The irrigation treatments were based on recent work by Goldhamer et al., (2006), showing that deficit irrigation is most effective when spread throughout the growing season. The approximate 5" and 10" irrigation levels were established by replacing drippers in the existing system, but using the same schedule of irrigation timing as used in the control. Applied water was measured with water meters and direct flow measurements on each dripper, as well as automated sensors for measuring system on time. Grids of 9 neutron access tubes were installed in a single quadrant of one tree in each drought treatment in 4 of the 5 plots. Measurements of midday stem water potential (SWP) were taken approximately weekly in the drought and 2 subsequent years. Soil moisture with neutron probes monthly in the drought and recovery year. Periodic measurements of canopy light interception were also made. SWP was measured on one central tree in each replication of each treatment (total of 40 trees).

Individual tree yield and dieback status was measured each year, with bloom status measured in 2010 and 2011.

Results and Discussion:

Treatments were applied in the simulated drought year of 2009 (**Table 1**), and neutron access tubes were measured to quantify the contribution of soil water to tree evapotranspiration (ETc). During the 2009 season there were approximately 2” of in-season rain, and in addition to irrigation water, trees in each of the drought treatments were able to obtain an additional 5-7 inches of soil water (**Table 2**). Soil water uptake was observed to the lowest depth measured (10’, data not shown). All trees survived to the 2012 season (with the exception of a few randomly distributed blow-over trees), and since the non-irrigated treatment trees only used a total of 7.6”, we conclude that almond tree survival may only require 7.6” of water.

Table 2. Contribution of irrigation, rain, and stored soil water to observed tree water use.

Treatment	Irrigation	Rain	Soil	Total	%ETc
0”	0”	2.1”	5.5”	7.6”	21%
5”	3.6”	2.1”	6.7”	12.4”	35%
10”	7.2”	2.1”	5.9”	15.2”	42%
Control	30.8”	2.1”	(?)	(32.9”)	(92%)

Pruning was accomplished by selective removal of scaffold branches (**Figure 1**), and resulted in an approximate 30% reduction in yield in 2009 (**Table 3**). Compared to non-modified (non-pruned) trees, yield was higher in 2010, but at the end of 4 years, there was no difference in average yield (**Table 3**). Since all trees survived the simulated drought in 2009, we were unable to evaluate whether pruning would improve survival. However, based on yield and the additional cost

Figure 1. Example of a control tree (left) and pruned/sprayed tree (right) on July 21, 2009. The 50% canopy reduction was accomplished by chainsaw removal of selected major scaffolds.

Table 3. Effects of canopy modification (pruning with or without Kaolin spray) on almond kernel yield. Note: P = pruned , S=sprayed

Year	Yield (pounds nutmeats/acre)	
	Non-modified	Pruned or P+S
2009	1030	730
2010	320	600
2011	1450	1170
2012	1540	1610
Average	1080	1030

of canopy modification, we conclude that there would be no clear economic benefit to canopy modification during a drought year.

Irrigation at any level (**Table 2**) was effective in moderating the degree of tree water stress, but as found in other studies, the level of stress experienced by any particular tree was influenced by factors other than the irrigation treatment (e.g., soil). However, when the trees were grouped based on the level of water stress experienced the pattern in yield over the 4 years of the study was very clear with greater levels of stress being associated with progressively lower yields, both in the drought year as well as the years following the drought (**Figure 2**).

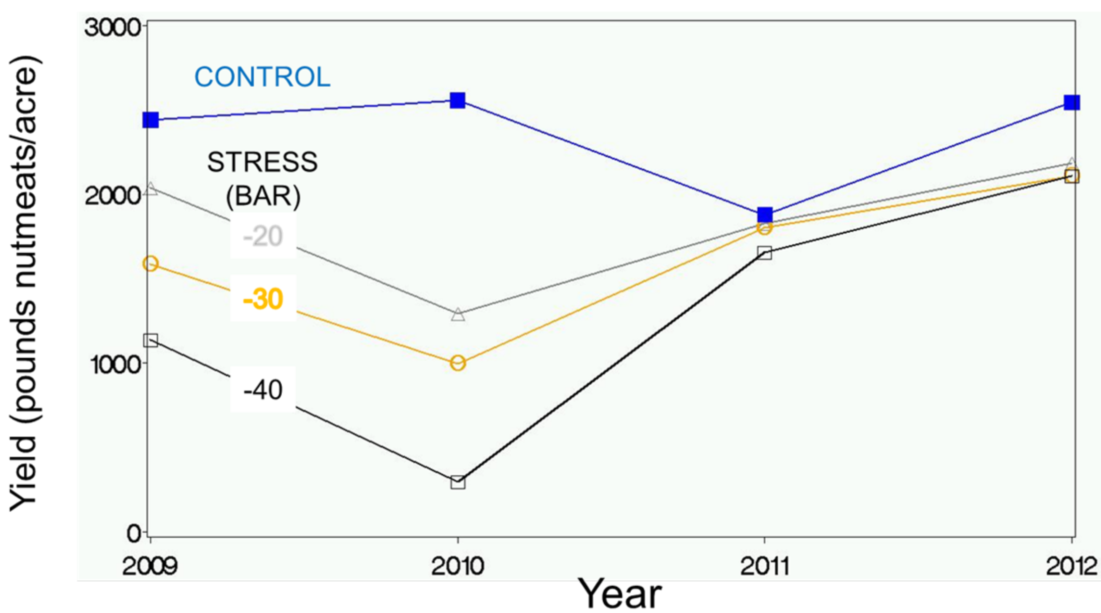

Figure 2. Four year pattern of kernel yield for trees grouped based on the level of stress experienced in the drought year (2009).

Table 4. Effects of the 2009 drought on flowering and fruit set in 2010.

Stress level (bar)	Flowering		Set	
	Number per branch area	(% of control)	%	(% of control)
-10 (control)	0.518	100	34.5	100
-20	0.445	86	22.1	64
-30	0.370	71	20.0	58
-40	0.185	36	12.8	37

Yields were reduced by water stress more in the year following drought (2010), than in the year of the drought (2009) and it appears that by 2011, the recovery in yield was largely complete (**Figure 2**). Since the yield effects of stress were consistent the over years and

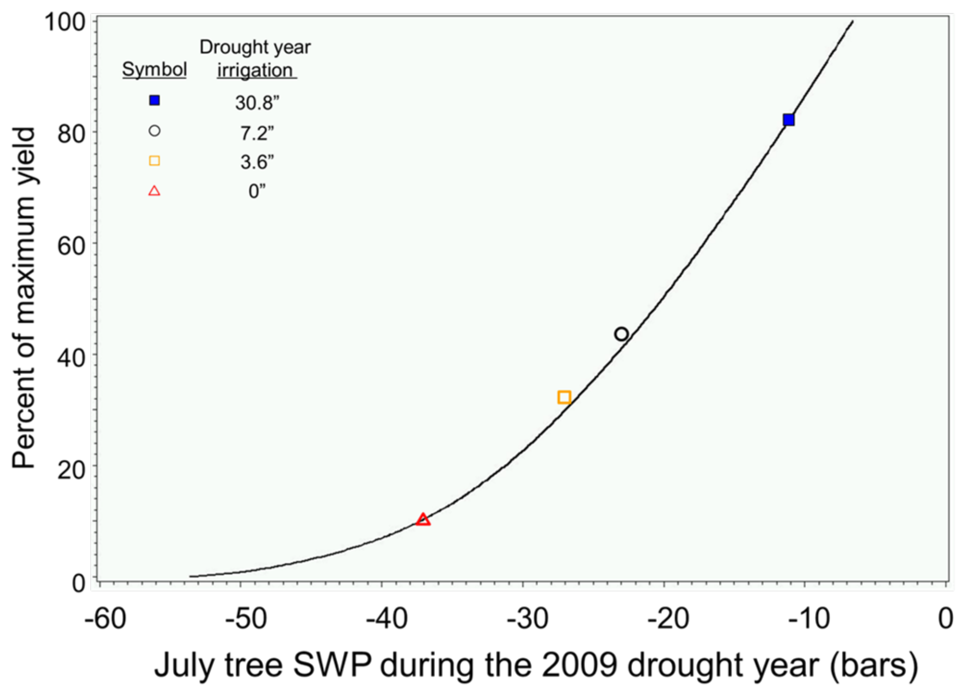

Figure 3. Modeled and observed relation of % maximum yield to the level of stress experienced in July of the previous year.

decreasing stress was associated with increasing yields, we conclude that application of even relatively modest amounts of water will increase tree health/yield, and presumably increase tree survival during a drought. Carryover effects of water stress were apparent in 2010 for both flowering (return bloom) as well as % set (**Table 4**). Since the effect of these two factors on yield will be compounded, estimates of the relative yield effects for a range of water stress were made and compared to the observed effects (**Figure 3**). These results indicate that almond yields may be substantially influenced by even modest levels of stress as a carryover effect.

Minimal twig dieback was observed in the drought year, and none of the drought Nonpareil trees of this study showed scaffold dieback at any time. However, by 2011 we were able to quantify a relatively linear relation between stress in 2009 and branch dieback; only at the most severe stress level (-50 to -60 bars SWP) did this dieback approach 20% (data not shown), indicating that the 50% canopy reduction was unnecessary. Based on an approximately linear relation between stress and dieback we conclude that there is no 'critical' level of stress for dieback to occur and even extreme levels of stress are not associated with substantial dieback. Some of the non-irrigated pollinator varieties (Monterey, Carmel) showed defoliation in 2009 and subsequent substantial canopy dieback. However as SWP was not measured on these trees, we do not know if these varieties experienced more stress than the Nonpareil variety or if they were more sensitive to the same level of tree stress.

Research Effort Recent Publications:

None at this time.

References Cited:

Goldhamer D.A., Viveros M., Salinias M. 2006. Regulated deficit irrigation in almonds: effects of variations in applied water and stress timing on yield and yield components. Irrig. Sci. 24(2):101-114.