Drought Survival Strategies for Established Almond Orchards on Shallow Soil

K. Shackel, J. Edstrom, A. Fulton, Br. Lampinen, L. Schwankl, A. Olivos, W. Stewart, S. Cutter, S. Metcalf, H. Munoz, G. Spinelli, F. Niederholzer

Primary questions of this research effort:

1) If there is a drought year, how much water will it take to keep my trees alive?

2) If I have no, or very little water, is there any cultural practice that will help the trees survive and/or reduce the negative carryover effects on tree yield?

Background: This drought study was performed on mature (19 years old in 2009), single line drip irrigated NonPareil almonds at the Nickels experiment station. In 2009, three irrigation and two canopy modification treatments were imposed (Table 1), in order to evaluate the ability of these strategies to reduce tree mortality under a single year drought scenario. This site was chosen based on previous research showing that the active root-zone of these trees was limited to about 3', and the soil had a low water holding capacity, both factors contributing to a potentially lethal level of drought stress. 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 at the deepest depth measured (10'), and after one year there was little canopy dieback apparent. Some of the non-irrigated pollinator varieties (Monterey, Carmel) did show substantial canopy dieback.

Summary objectives/questions for the study (2009 - 2012)

1) **How much water does an almond tree require to survive?**
2) **Under non-irrigated (rain and stored soil moisture only) conditions, will survival be improved by 50% canopy reduction and/or kaolin (surround) spray?**
3) **Will application of small amounts of water (5", 10") over the season improve tree health and/or survival?**
4) **Is there a critical level of tree water stress that is necessary to cause tree death or substantial tree dieback?**

Table 1. Treatments applied 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

Results, question #1:
Treatments were applied in the simulated drought year of 2009 (Table 1), and an extensive system of neutron access tubes were installed in the drought treatment plots to quantify the contribution of soil water to tree evapotranspiration . During the 2009 season there was about 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 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%)

Results, question #2:
Pruning was accomplished by selective removal of scaffold branches (Figure 1) , and resulted in about a 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 of canopy modification, we conclude that there would be no economic benefit to canopy modification during a drought year.**

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.

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

Results, question #3:
Irrigation at levels substantially below that of the control (Table 2) reduced the level of plant 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 (data not shown), However, when the trees were grouped based on the level of water stress experienced, the patterns in yield over the 4 years of the study were very clear, with greater levels of stress being associated with progressively lower yields, both in the drought year, as well as the year following the drought (Figure 2). Yields were more reduced by water stress 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 over years, and 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, if stress under non-irrigated conditions is severe enough.**

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.**

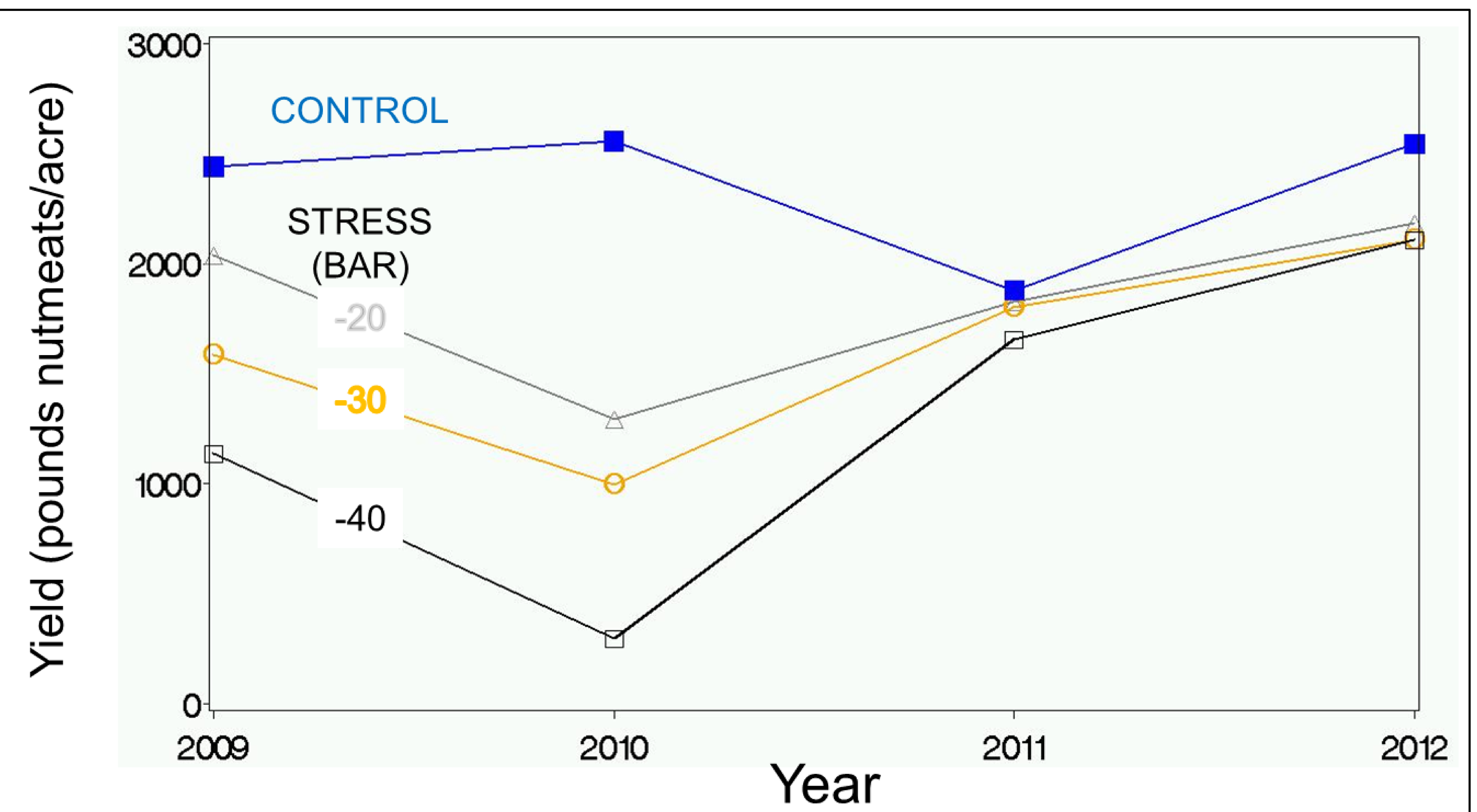

Figure 2. Four year pattern of kernel yield for trees grouped base on the level of stress experienced in the drought year (2009).

Results, question #4:
Minimal twig dieback was observed in the drought year, and none of the droughted 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 and branch dieback, but only at the most severe stress level (-50 to -60 bars SWP) did this dieback approach 20% (data not shown). Based on the linear relation between stress and dieback **we conclude that there is no 'critical' level of stress for dieback to occur, and that even extreme levels of stress are not associated with substantial dieback.**

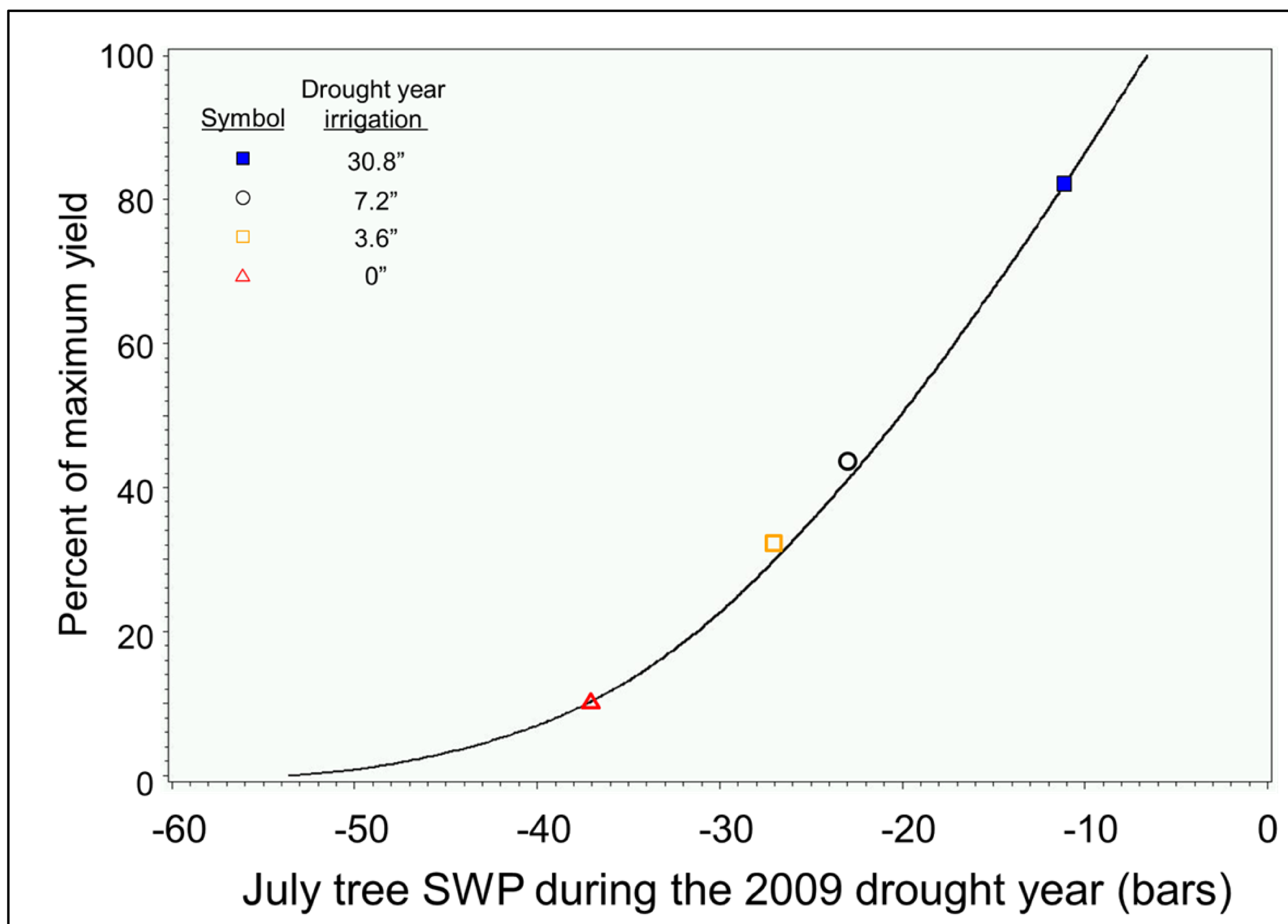

Figure 3. Modeled and observed relation of % maximum yield to the level of stress experienced in July of the previous year.

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

Summary and Conclusions for Drought Survival Strategies in Almonds:

- **7.6" of water use may be sufficient for almond survival**
- **Canopy modification (pruning or spraying with Kaolin) are not effective**
- **Any amount of irrigation will improve tree health and yield**
- **Limb and twig dieback are progressive effects of increasing stress, and not symptoms that occur at a 'critical' level of stress**