Drought Survival Strategies for Established Almond Orchards on Shallow Soil

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OBJECTIVES

1. Determine the current year effects and carryover effects of 50% canopy reduction or kaolin (surround) spray under non-irrigated (rainfed) conditions on tree production and survival.
2. Determine the current year effects and carryover effects of an irrigation restriction to 5" and 10" of applied water on control (unsprayed) and kaolin sprayed tree production and survival, compared to fully irrigated control trees.
3. Estimate the total quantity of water required for survival of almond trees under extreme water stress conditions.
4. Determine the critical level of tree water stress necessary for tree death or dieback.

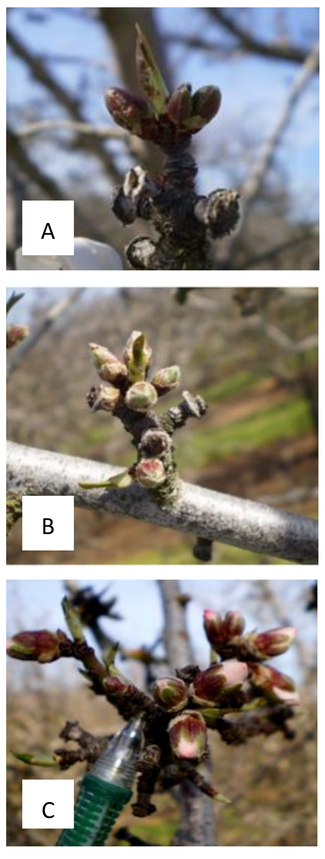

Figure 1. Flower development on 02/16/10 for three seasonal average levels of SWP during the 2009 season: A, -32 bars, first swell/green tip; B, -24 bars, green tip; C, -11 bars, first pink.

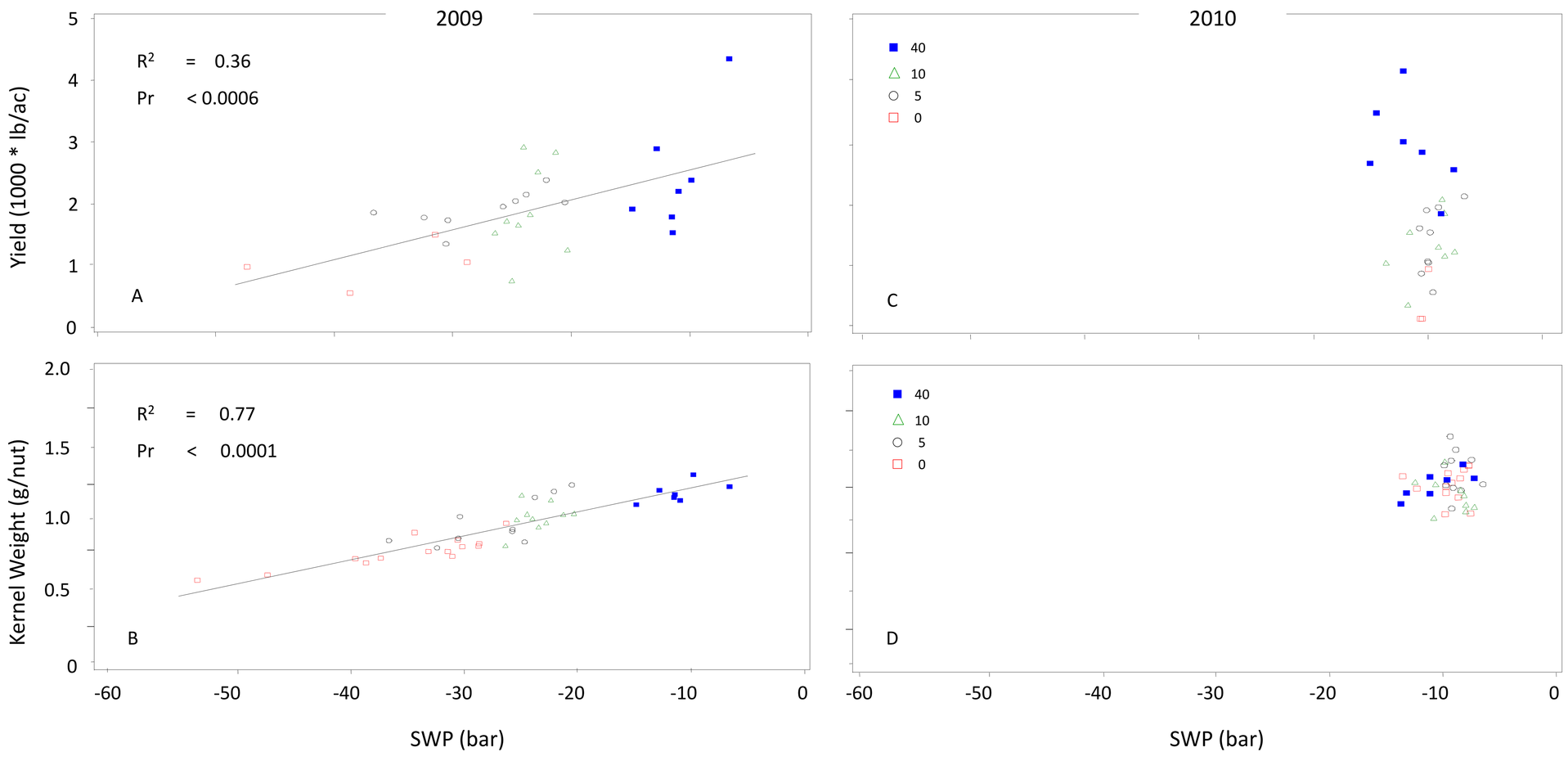

Figure 2. Current year effects of sustained water stress applied in 2009 in the yield and kernel weight for 2009 (A,B) and 2010 (C,D).

RESULTS

In 2010, the flower development was delayed by the stress in 2009. For example, on 2/16/10, one of the more stressed trees (Fig. 1.A) was in first swell/green tip, whereas a tree with an average SWP value of -11 bars in 2009 was in first pink (Fig. 1.C) .

In 2009, the year of water stress, both kernel weight and yield were reduced by stress (Fig. 2A, B), but kernel weight (Fig. 2B) showed a stronger relation to stress than yield (Fig. 2A). In 2010, only a narrow range of stress (SWP) occurred, because all trees were irrigated normally, and while there was a large range in yields (Fig. 2C), there was no apparent relation of yield or kernel weight to SWP.

In order to evaluate the carryover effects of stress in 2009 on fruit set, kernel weight, and yield in 2010, these variables were plotted as a function of the amount of stress (SWP) measured in 2009 (Fig. 3). A strong carryover effect was apparent for yield (Fig. 3A) and fruit set (Table 2), but not for kernel weight (Fig. 3B).

In 2009, canopy reduction was considered to decrease the water stress experienced by the trees as well as to enhance their survival under extreme water conditions. This management partially decreased the water stress in the 0" irrigation treatment in 2009 (previous report); and the yield was not significantly decreased by pruning but there was a negative trend in this parameter (Table 1). In 2009, nut size was not affected by pruning although there was a positive effect in the 0" irrigation treatment. Results for nuts per tree were not consistent because pruned trees (P) were not significantly smaller than non-pruned (NP) but pruned/sprayed trees (PS) were. In 2010, there were not significant differences in yield, nut size and nuts per tree for canopy modification (Table 1). However, the highest number of nuts per tree was measured in P trees of 0" irrigation, indicating that water stress could enhance this variable when canopy is decreased to 50%.

In both 2009 and 2010 water stress decreased yield (Table 2). This variable was explained by nut size in 2009 and number of nuts per tree in 2010. The decrease in yield in 2010 could be attributed to decreases in both the number of flowers and fruit set (Table 2). An increase in the number of flowers with 10" of irrigation is interesting, and agrees with previous research showing a positive effect of stress on flowering. The small difference between the 10" and 5" irrigation treatments for fruit set, nuts per tree and yield may be explained by the overlapping of SWP ranges in those treatments.

Considering that one of the trees reached a SWP value of -63 bars in 2009 and it is still alive, this level of water stress is apparently not sufficient to cause tree death (2009 report).

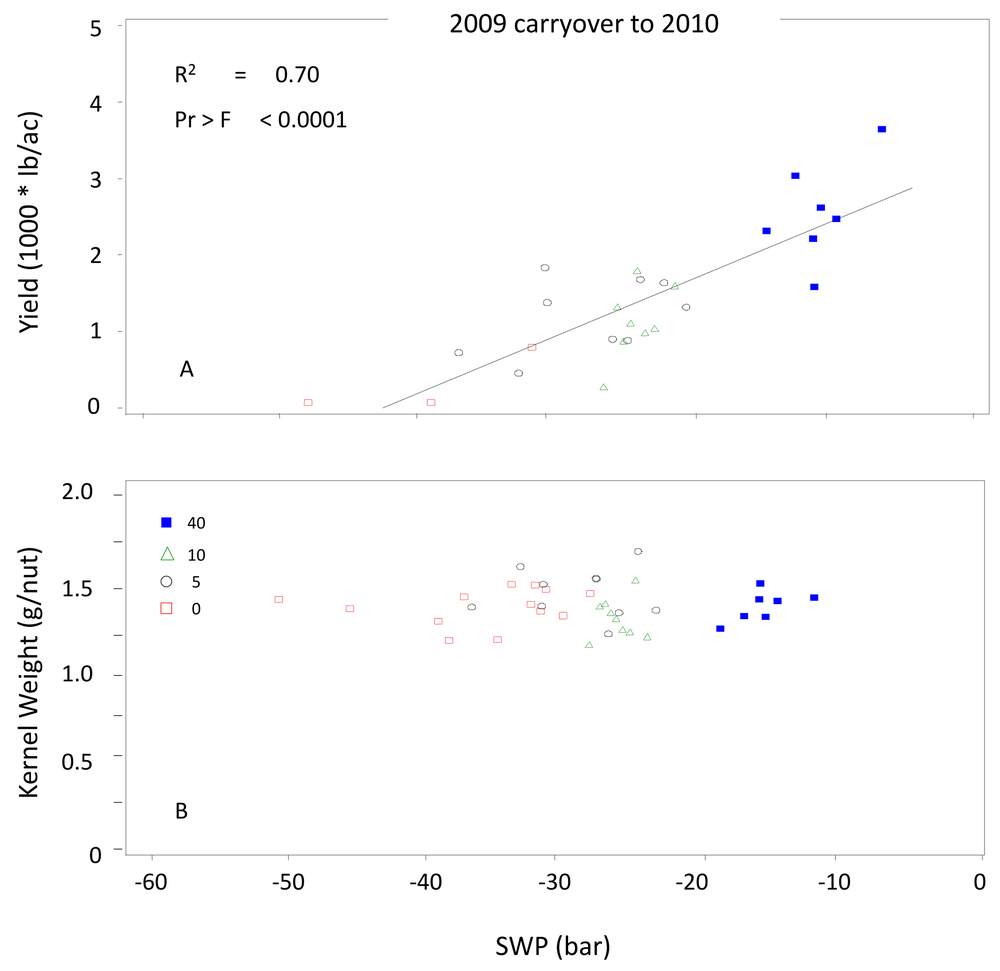

Figure 3. Carry-over effects of sustained water stress applied in 2009 in yield (A) and kernel weight (B).

CONCLUSIONS

1. All trees survived one year after water stress was applied, supporting earlier conclusions that 7.6" of water may be sufficient for almond tree survival in these conditions (Almond Board of California 2009 report).
2. Carryover effects were observed in flowering, fruit set, number of nuts per tree and yield, but not on kernel weight. Flowering was delayed by stress, and even though increased flowering was associated with the 10" irrigation treatment, fruit set was less, which resulted in negative overall carryover effects on yield in this treatment and all other stress treatments.
3. Canopy management (pruning, spraying) had no effect on tree survival, and no statistically significant effect on yield, although removing 50% of the canopy numerically reduced yields.
4. A SWP value of -63 bars was exhibited by one tree in the study without tree death. This fact indicates that this value is not lethal and is consistent with the belief that almond trees are very drought resistant.
5. Twig dieback occurred in both stressed and non-stressed trees, but was not severe in any treatment. More dieback was observed in guard trees of the Monterey and Carmel varieties, indicating that these varieties may not be as drought resistant as Nonpareil.

Table 1. Effects of canopy modification in 2009 (NP: non pruned, S: sprayed, P: pruned, PS: pruned and sprayed) in yield, nut size and nuts/tree for three irrigation treatments (0”, 5”, and 10” of water applied in 2009).

	2009			2010			Cumulative (%) [a]
Yield (lb/ac)	10	5	0	10	5	0	
NP	1890	2020	1030	1350	1010	320	(100)
S	1910	1800	---	910	1450	---	97
P	---	---	860	---	---	770	121
PS	---	---	590	---	---	430	76
Nut size (g/nut)							
NP	1.04ab	1.00	0.70	1.30	1.40	1.30	(100)
S	1.00b	1.00	---	1.30	1.40	---	99
P	---	---	0.80	---	---	1.40	91
PS	---	---	0.80	---	---	1.40	110
Nuts / tree							
NP	6810	7800	5240a	4400	3220	850	(100%)
S	7560	6740	---	3320	3780	---	96
P	---	---	3980ab	---	---	2340	104
PS	---	---	2850b	---	---	990	63

a. Calculated as a percentage of the accumulated value in 2009 and 2010 for all the irrigation treatments.

Table 2. Effect of four irrigation treatments (0”, 5”, 10”, 40” control) applied in 2009 in flowers, fruit set, nut size, nuts per tree and yield.

Irrigation rate (in)	SWP range (bar)	Flowers (#/bxsa)	Fruit set (%)	Yield (lbs/ac)		Nut Size (g/nut)		Nuts (#/tree)	
2009	2009	2010	2010	2009	2010	2009	2010	2009	2010
40 (Control)	-14.8 to -6.6	0.52b	36a	2224 a	2560 a	1.16 a	1.38 ab	7650	8150 a
10	-26.4 to -20.3	1.15a	10bc	1890 ab	1130 b	1.04 ab	1.29 b	7140	3860 b
5	-36.7 to -20.5	0.44b	19b	2020 ab	1204 b	0.97 b	1.43 a	7330	3470 b
0	-53.6 to -26.3	0.14c	6c	1030 b	320 c	0.72 c	1.32 ab	5240	852 c