MANAGING HEAT AT BLOOM IN 'FRENCH' PRUNE, 2009

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PROBLEM AND ITS SIGNIFICANCE

Excessive heat at bloom is linked to significantly reduced prune production in key California growing regions in three of the last six crop years (2004, 2005, and 2007). Total grower economic losses in Sutter and Yuba Counties – with 40% of the prune acres in the state -- were in the range of $240 million for those three years, based on county ag commissioners' data. Overall economic damage to the regional economy was probably 1.5x that loss -- $360 million. As the probability of heat in March appears to be increasing (Rick Snyder, personal communication), California prune growers must develop management strategies to mitigate heat damage at bloom to remain economically viable.

Recent research results show that temperatures >75^{o}F begin to negatively affect pollen tube growth rate and viability, but research has not identified 1) temperature thresholds for actual crop damage and 2) practices to reduce orchard temperature once those thresholds have been reached. Prune growers currently use irrigation water as the most cost-effective means of modifying orchard temperature. Freezing of water releases energy that is used to protect crops from temperatures below 32^{o}F. Evaporative cooling is a common practice in apple production to reduce sunburn, and appears to be the most cost-effective approach to reducing temperatures in prune orchards when hot weather occurs at bloom.

Research must answer three questions:

1. What is/are the threshold temperature(s) that affect prune set and crop yield?
2. Can orchard temperatures be lowered using irrigation water?

OBJECTIVES

- Determine bloom-time temperature thresholds above which crop damage occurs.

- Evaluate under-tree orchard cooling with micro-jet sprinklers for improving prune set during hot weather at bloom.

PROCEDURES

Glenn, Tehama, and Sutter Counties:

Temperature and relative humidity sensors were placed in commercial orchards in each county. Sensors were located at 5-6' feet off the ground in exposed sites between trees in the tree row. They were not placed in tree canopies. In a few locations, sensors were placed at 5' and 10' in the same location in an effort to evaluate affect of sprinkler cooling on orchard temperatures. Temperatures in each block were continually recorded during bloom at all sites.

Bloom progression was measured by counting open flowers on short branches at roughly 6' height around 3 trees in each orchard. Initial set was measured in the first week of May.

Yolo County:

Additional heat was placed near a tree during bloom to increase the afternoon temperatures. The experiment took place at the Univ. Calf. Wolfskill Experimental Orchards in Winters, California. An 8 foot tall gas burning patio heater with a downward heat deflecting top shield was placed on the south side of a prune tree growing in a production style orchard. Fifteen branches were chosen at random in the vicinity of the heater. Five control branches were chosen on the adjacent tree as controls. The heater was turned on in the afternoon from 12-4pm when the weather permitted through bloom; March 18, 19, 20, 24, 25, and 26. If the wind was blowing too strongly the heater was not turned on. Temperature data was collected separately on each test branch using Onset Hobo data loggers. One logger with a solar radiation shield placed on a pole between trees was used to collect the ambient temperature. This ambient temperature data were used to estimate the temperature of the control branches. The numbers of flower buds were recorded for each branch. The fruit set was counted 46 days after full bloom (May 9th) and 118 days after full bloom (July 20th). The numbers of hours each branch received above 75° F and 85° F was calculated using the average temperature of 15 minute increments

RESULTS AND DISCUSSION

Glenn, Tehama, and Sutter Counties:

Maximum temperatures at full bloom were high in 2009 in the Sacramento Valley (average full bloom max temperature = 75.4^{o}F). Despite this, average set in commercial orchards in Sutter, Glenn, and Tehama counties averaged from 16-50%, with an overall average of 30% across all 18 orchards in the study (see Table 1). These data indicate that trees at full bloom under conditions where maximum daily temperatures range between 75-80^{o}F can set commercially viable crops.

Field data from the 2005 and 2007 bloom seasons, when very low set levels were observed, show that maximum temperatures at full bloom were between 80-85^{o}F for 2-3 consecutive days. In those years, flowers were exposed to 11 (2007) or 13 (2005) total hours of temperatures over 80^{o}F, with continuous exposure to >80^{o}F temperatures ranged from 3-6 hours per day.

Our results suggest that risk to commercial prune production may be greater when flowers are exposed to 10 or more hours of temperatures over 80°F compared to less than 5 hours over 80 °F. More work is needed to confirm this idea.

Measurements of orchard temperatures at 5 feet vs. 10 feet did not show a significant change when orchards were irrigated to reduce heat risk to the crop. Instead, changes in temperature in the orchard between 5 and 10 height were largely due to interactions between distance from the orchard floor and time of day. Temperatures near the ground (5') were lowest in the early morning relative to the measurements at 10', and relatively warmer in the late morning/early afternoon (Figure 5). In this orchard, irrigating at full bloom decreased orchard temperatures no more than 1°F at 5' compared with the temperature at 10'.

Relative humidity differences between 5' and 10' height in the orchard were also relatively minor in all the orchards irrigated at full bloom. Differences in relative humidity from 5'-10' were, at a maximum, only 10%, with the majority of values showing a difference of <5%. Differences in relative humidity between 5' and 10' feet -- from the same orchard as in Figure 5 -- are shown in Figure 6.

Large differences in relative humidity between 5' and 10' height in the orchard were measured in at least one location, but this orchard was not irrigated at bloom and fruit set was not affected.

We could measure no significant cooling or increase in relative humidity in orchards irrigated at full bloom. Irrigation at bloom may improve fruit set, but we haven't been able to measure changes in orchard micrometeorology that could support such benefit.

Yolo County:

Bloom had just begun at the time of the heater placement on March 18th and continued through March 28th. Full bloom (90% of the flowers open) was March 24th.
There was a definite difference between the temperatures of the test branches. Figures 1-2 show examples on the variation in temperatures recorded on the branches each day. Three of the branches were too close to the heater and were burnt. These branches were removed from the data set. Another branch was removed from the data set due to the data logger malfunctioning. Of the five control branches, only four remained in the final set due to the tractor hitting the branch and removing all the fruit. The final data set contains 11 test branches and four control branches. Table one shows the accumulated number of hours the test branches were exposed to temperatures between 75-79, 80-85, 86-90, > 90, and the total hours above 75 ° F and 85° F. Fruit set of the branches ranged from 11.2- 50.7 % on 46 days after full bloom and dropped to between 0- 48.7 % 118 days after full bloom (Table 2).
The regression analysis for comparing the fruit set to the number of hours the branch was above 75 ° F was significant negative correlation for 46 days after full bloom (p value= 0.001; adj. Rsqr = 0.534) and for 118 days after full bloom (p value= 0.001; adj Rsqr= 0.353). (Figure 3)
The regression analysis for comparing the fruit set to the number of hours the branch was above 85 ° F was significant negative correlation for 46 days after full bloom (p value= 0.001; adj. Rsqr = 0.359) and for 118 days after full bloom (p value= 0.001; adj Rsqr= 0.520). (Figure 4)

CONCLUSIONS

Yolo County:

The results of this experiment show that there is a strong negative relationship between the early fruit set and the amount of time the tree is exposed to temperature over 75 ° F while the flowers are in bloom. This has been shown in previous studies. The interesting observation that is shown for the first time in this experiment is that final fruit set may be even lower with exposure to temperatures over 85 ° F.

Table 1. Average prune fruit set, full bloom dates, and maximum temperatures in orchard at full bloom for individual orchards in Sutter, Glenn and Tehama Counties, 2009. Set was measured between May 1-10.

Orchard	Maximum Temperature at 80-100% full bloom	% Fruit Set
Sutter 1	75°F	37%
Sutter 2	74 °F	27%
Sutter 3	72 °F	30%
Sutter 4	71 °F	21%
Sutter 5	80°F	19%
Sutter 6	75°F	18%
Glenn 1	78 °F	31%
Glenn 2	78 °F	24%
Glenn 3	78 °F	48%
Tehama 1	79°F	18%
Tehama 2	79 °F	16%
Tehama 3	71 °F	30%
Tehama 4	74 °F	34%
Tehama 5	79 °F	53%
Tehama 6	75 °F	26%
Tehama 7	71 °F	28%
Tehama 8	78 °F	50%
Tehama 9	71 °F	26%

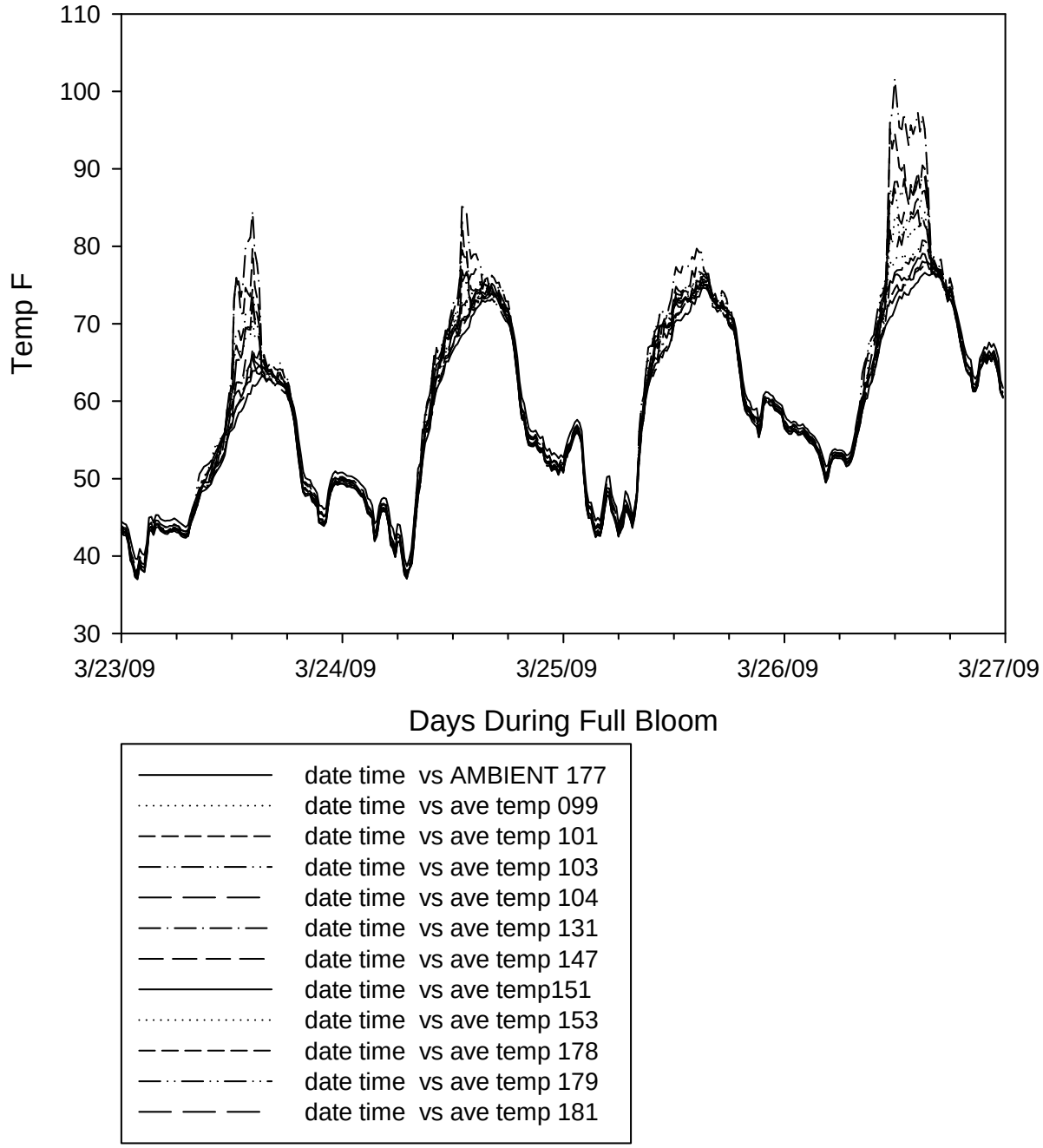
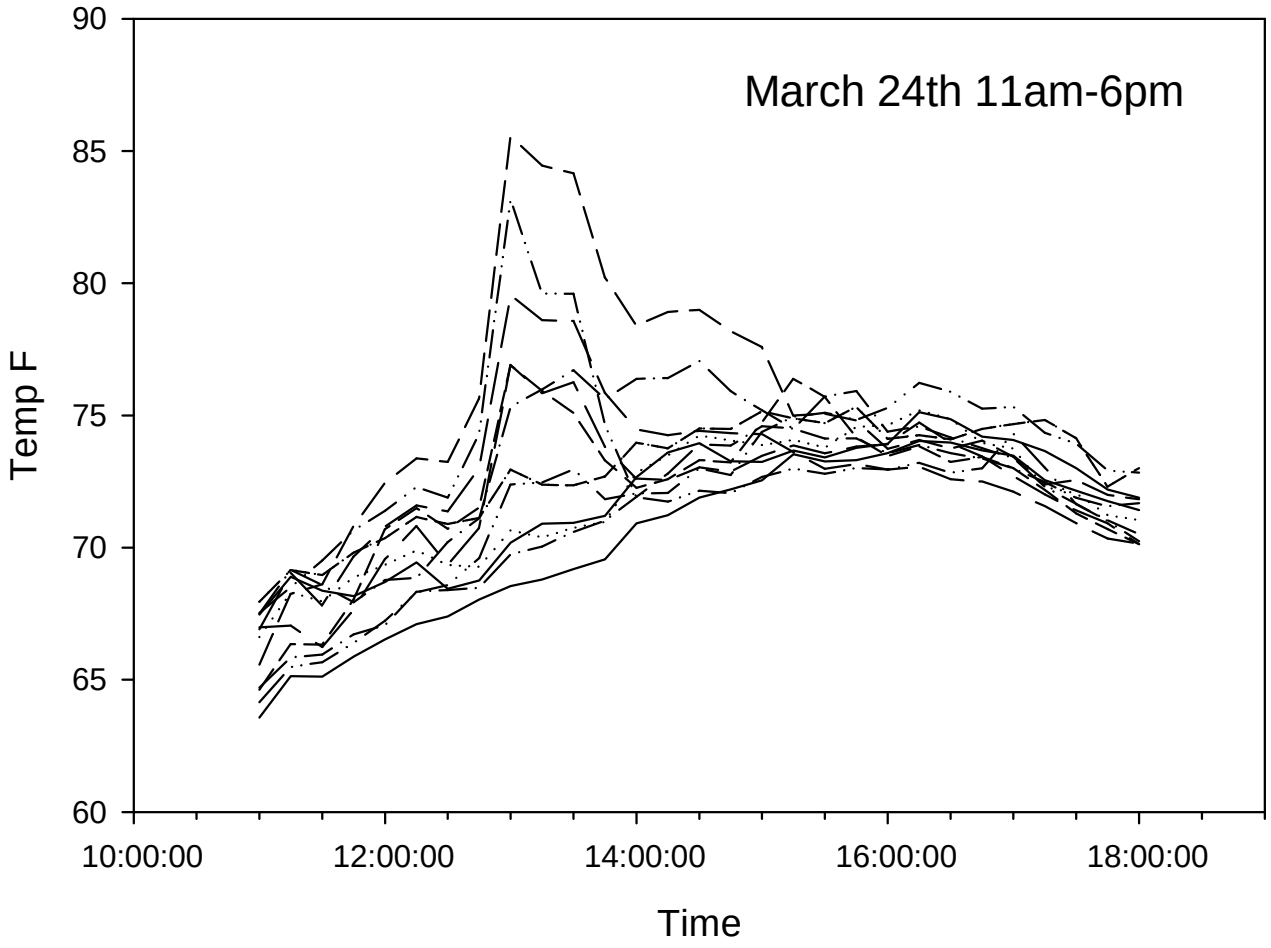


Figure 1. Temperature of the test branches over the period of full bloom (March 23-26, 2009) with the heater turned on in the afternoon.


March 24th 11am-6pm
Temp F
90
85
80
75
70
65
60
10:00:00
12:00:00
14:00:00
16:00:00
18:00:00
Time

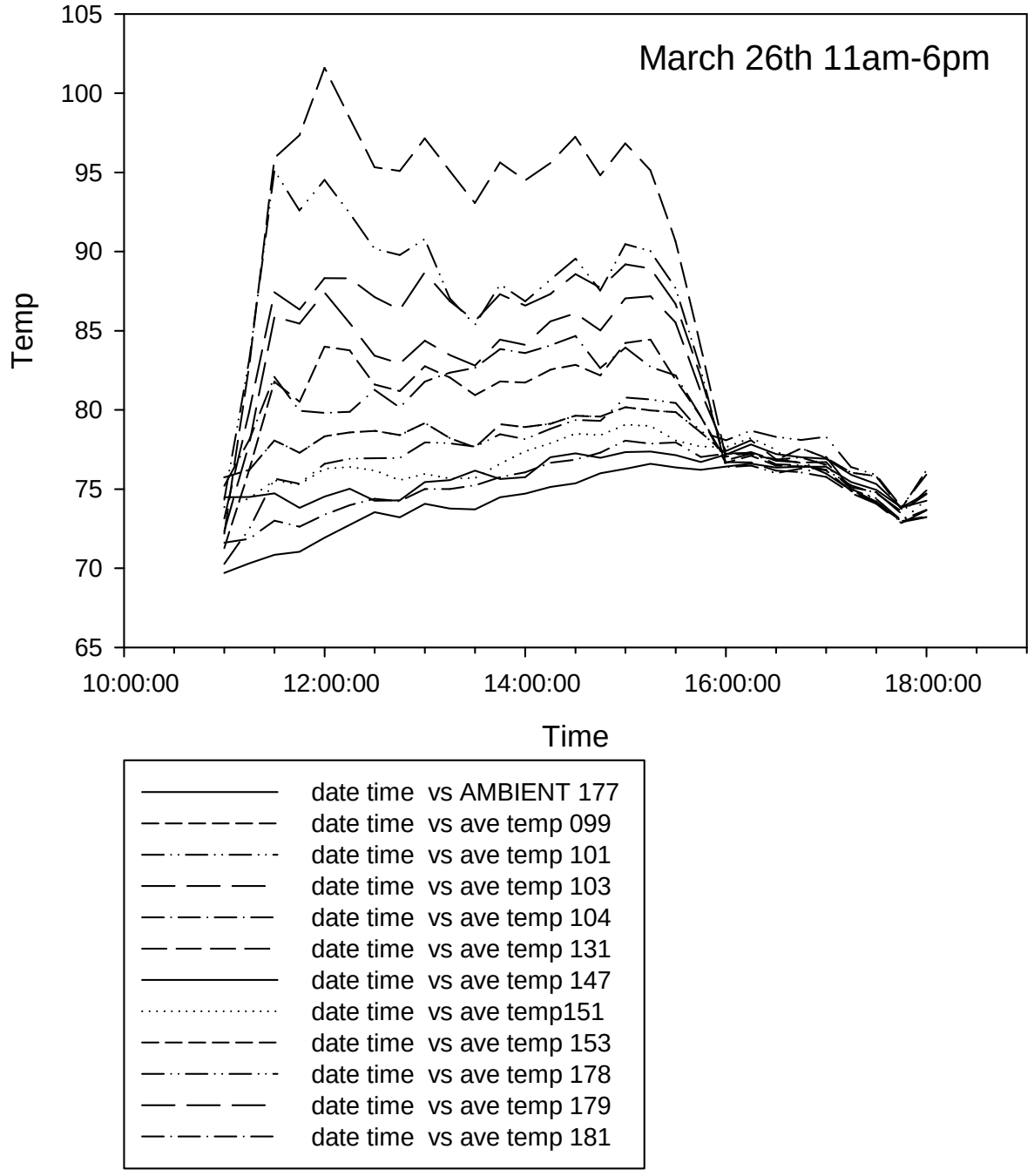


Figure 2. Temperature of the test branches on March 24 (full bloom) with the heater on from 12:30 to 4 pm and March 26 with the heater on from 11:30 to 4 pm.

Table 2. Fruit set on May 9 and July 20 of the test and control branches with the duration of time (hours) over the bloom period (March 18-28) that the test branches were exposed to temperatures between 75-79, 80-85, 86-90, > 90, and the total hours above 75 ° F and 85° F.

Branch and Hobo ID	% set May 9 (46 days)	% set July 20 (118 days)	hours of 75-79°F	hours of 80-85°F	hours of 86-90°F	hours above 90°F	Total Hours above 75°F	Total Hours above 85°F
1232-099	29.7	27.0	31.00	8.00	0.75	0.00	**39.75**	**0.75**
1232-101	17.6	15.7	28.75	9.00	0.00	0.00	**37.75**	**0**
1232-103	25.8	0.0	15.50	13.25	3.25	0.00	**32.00**	**3.25**
1232-104	23.1	25.9	24.75	4.75	1.00	0.00	**30.50**	**1.00**
1232-131	11.9	0.0	21.75	11.75	1.00	11.75	**46.25**	**12.75**
1232-147	28.8	25.4	28.25	4.00	0.00	0.00	**32.25**	**0**
1232-151	22.2	9.5	26.25	4.75	1.25	0.50	**32.75**	**1.75**
1232-153	35.7	26.2	23.25	8.00	4.00	0.00	**35.25**	**4.00**
1232-178	13.3	0.0	13.75	9.50	4.25	7.75	**35.25**	**12.00**
1232-179	17.2	0.0	13.25	7.00	7.75	3.50	**31.50**	**11.25**
1232-181	19.2	13.5	23.75	12.00	3.25	0.00	**39.00**	**3.25**
ambiant-2	43.1	35.3	21.00	1.00	0.00	0.00	**22.00**	**0**
ambiant-3	50.7	38.0	21.00	1.00	0.00	0.00	**22.00**	**0**
ambiant-4	49.7	48.7	21.00	1.00	0.00	0.00	**22.00**	**0**
ambiant-5	29.5	23.7	21.00	1.00	0.00	0.00	**22.00**	**0**

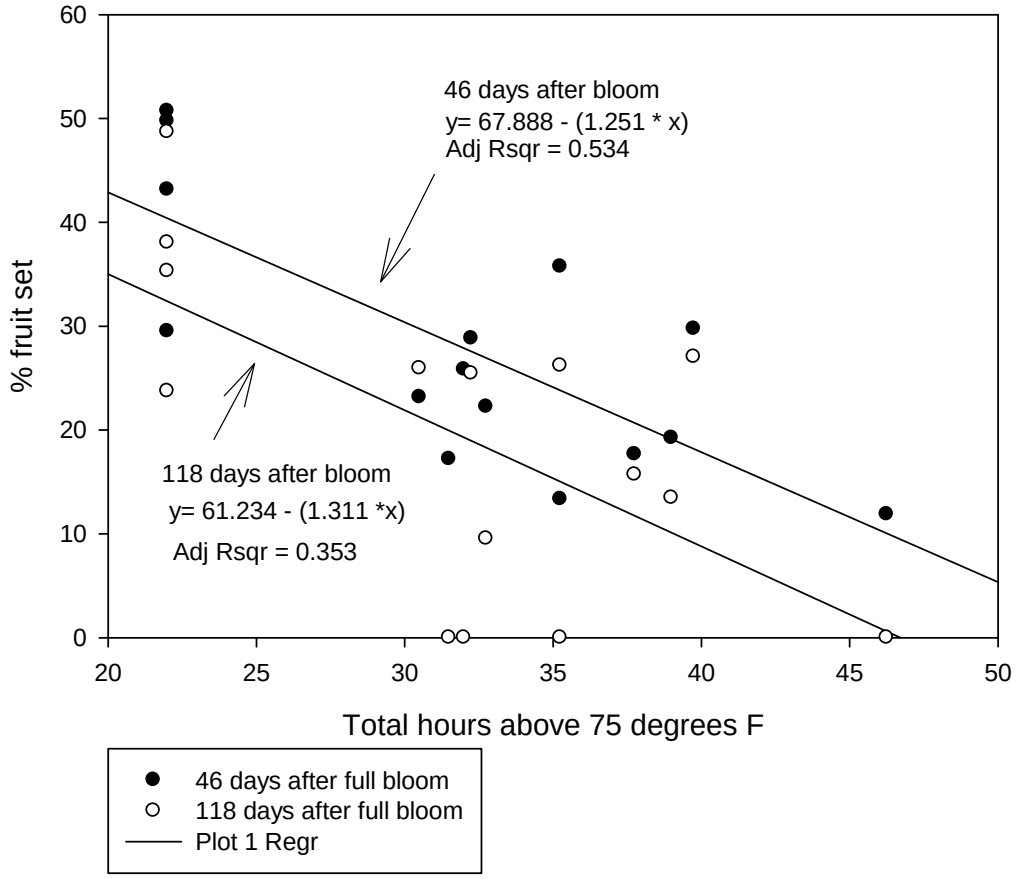


Figure 3. Regression comparison of the percent fruit set at 46 and 118 days after full bloom to the total hours above 75°F that each of the 11 test branches were exposed to over the period of bloom (March 18-28) including an additional four control branches that had 22 hours above 75°F over the same period.

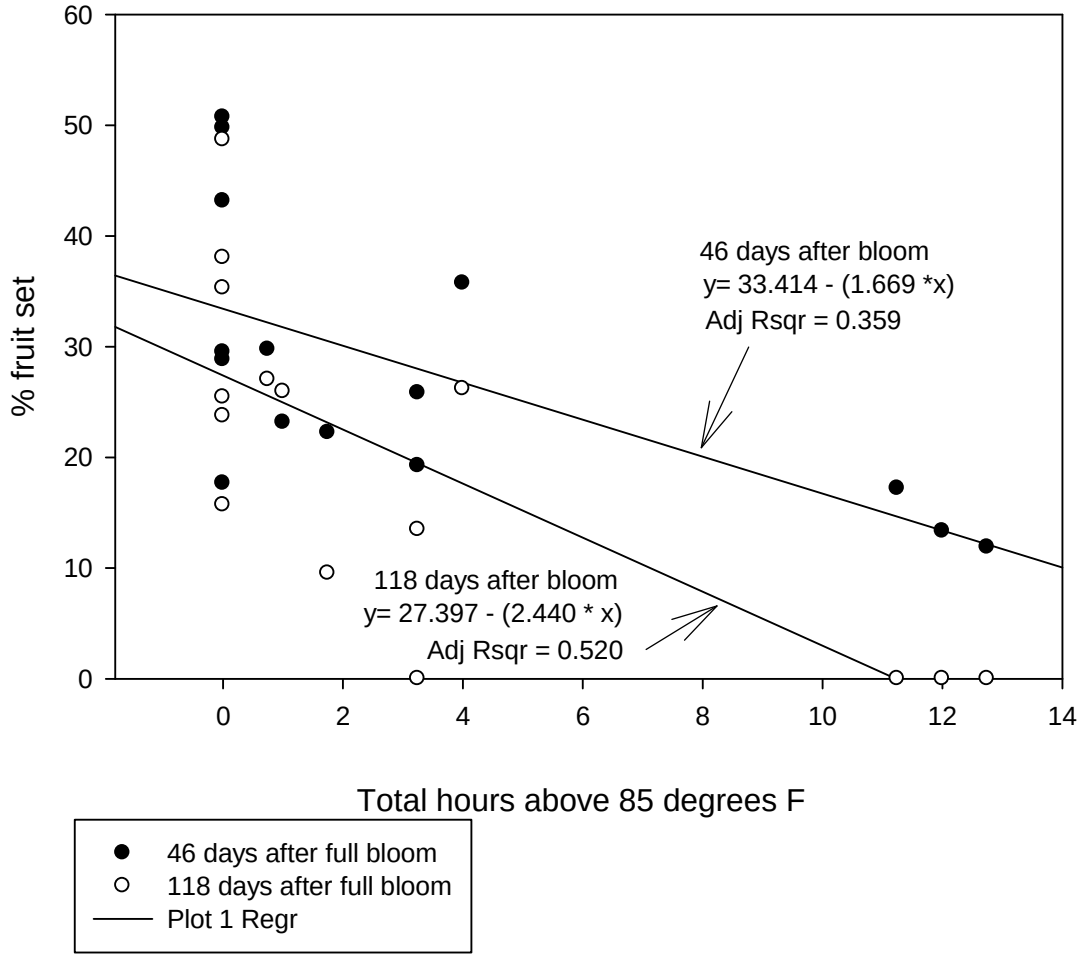


Figure 4. Regression comparison of the percent fruit set at 46 and 118 days after full bloom to the total hours above 85°F that each of the 11 test branches were exposed to over the period of bloom (March 18-28) including an additional four control branches that had 0 hours above 85°F over the same period.

Figure 5. The difference in orchard temperature, recorded hourly, between 5' and 10' from the orchard floor. Negative numbers reflect warmer temperatures at 10' relative to 5'. Positive numbers reflect the opposite relationship.

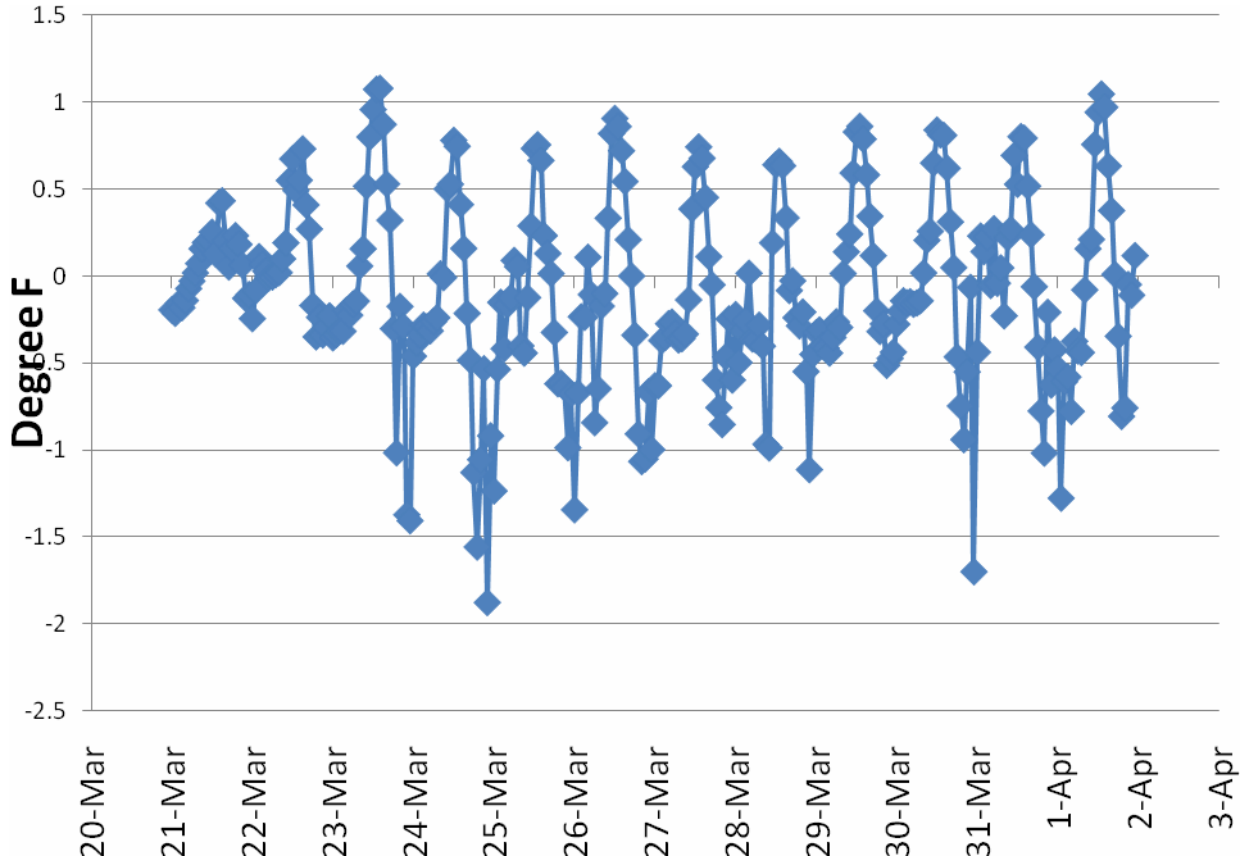


Figure 6. The difference in relative humidity, recorded hourly, between 5' and 10' above the orchard floor. In this graph, negative numbers reflect higher humidity at 5' relative to 10'. Positive numbers reflect the opposite relationship. Irrigation was run beginning around Mar 22 and running for upto a week. The low spikes in RH seen after Mar 22 are all between 9PM and midnight. Difference in daytime RH between 5' and 10' was only 2-3%, maximum.