Almond Stockpile Monitoring for Aflatoxin Potential

Project No.: **09-AFLA2-Lampinen**

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Objectives:

The objectives of this study are to study the process of stockpiling including examining temperature and moisture conditions in stockpiled almonds in different production areas in California. A second goal is to determine the impact of different tarp materials on stockpile conditions. A third goal is to examine variability in nut drying on the orchard floor as it relates to position in the orchard and midday canopy light interception. The ultimate goal is to develop recommendations for stockpiling that minimize potential for growth of *Aspergillus* spp. (*A. flavus* and/or *A. parasiticus*) that result in aflatoxin contamination of nuts. In addition, monitoring of an ongoing trial with varying levels of canopy cover will be continued to provide orchard level environmental data as well.

Interpretive Summary:

Almond stockpiles in Kern, San Joaquin and Glenn Counties were monitored following the 2007 and 2008 harvests. For details see the Almond Board Annual reports from 2007 (07-AFLA2-Lampinen) and 2008 (08-AFLA2-Lampinen). Of particular note in 2007/2008 season, stockpiling of nuts with a water activity notably above the recommended 0.65 - 0.70 (= equilibrium relative humidity of 65 - 70%, see below for explanation) resulted in significant mold growth near the pile surfaces. The two piles where this was observed had initial moisture contents of: 1) hulls 13.1% and kernels 5.2%(total fruit moisture content 9.2%); and 2) hulls 12.0% and kernels 7.3% (total fruit moisture content 9.7%). There was *Aspergillus* growth at the top and bottom edge of

these stockpiles and analysis of one pile showed this was associated with aflatoxin production.

In 2009, the main goal of this project was to investigate the impact of different tarp materials (clear, white and white/black) on stockpile conditions as they relate to aflatoxin potential. Six stockpiles were set up in Kern County. Three stockpiles were taken from an orchard that tends to be harvested somewhat wetter and three piles were taken from an orchard that tends to be harvested drier. The stockpiles were outfitted with temperature and relative humidity sensors at three depths in the stockpiles and temperature sensors near the surface of the pile where condensation has been observed in the past. Stockpiles for the 2009 harvest season are still in place at the time of report writing. Preliminary results suggest that the stockpiles with clear tarps are significantly hotter, and have significantly larger day/night temperature swings than either the stockpiles with white or white/black tarps, creating more potential for condensation (**Figure 2**). The smaller temperature swings under the white and white/black tarps should result in less potential for condensation.

<u>2007 and 2008</u>
Results from 2007 and 2008 suggested that high moisture content of nuts and varying temperatures resulting from solar heating and cooling lead to uneven moisture distribution in stockpiles. Condensation of moisture against tarps occurs when warm air heated on the south and west sides of the pile cools. For detailed data from stockpile temperature and relative humidity dataloggers for the 2007 and 2008 seasons, please see the 2007(07-AFLA2-Lampinen) and 2008 (08-AFLA2-Lampinen) Annual Reports. To briefly summarize the results, temperatures at all locations inside the pile tended to be higher than ambient temperatures. Temperature at higher positions in the stockpiles tended to be greater and relative humidity lower compared to that in lower positions. Differences in temperature between high and low positions in the piles tended to get less through the storage period. As expected, temperatures in the stockpiles decreased as the season progressed. Since the air in the stockpile is at equilibrium with the nuts and hulls, the water activity in the pile should be equal to the (relative humidity)/100 as shown on the bottom axis of **Figure 1**. These data agree well with published recommendations on almond storage in the UC Almond Production Manual, Page 275 (UC Division of Agriculture and Natural Resources, Publication 3364). The levels of relative humidity in the Kern County stockpiles were well below the 65 – 70% relative humidity recommended in the UC Almond Production Manual (Page 275) to balance the mold growth potential with optimal texture, color, flavor and stability. In contrast the relative humidity in the San Joaquin 1 and 3 piles went above this level and there was *Aspergillus* growth and aflatoxin production. King et.al. (1983) found that fungal growth occurred at a water activity greater than 0.75 which is equal to an equilibrium relative humidity greater than 75%.

<u>2009</u>
Preliminary results suggest that stockpiles with different tarp materials have had substantially different temperature profiles (**Figure 2**). Detailed results for the 2009 stockpiles will be presented in the 2010 report to the Almond Board since stockpiles will not be removed until early 2010.

Because of the problems that can occur when nuts are stockpiled with excessive moisture, one of the objectives of this project is to develop methods of assessing nut moisture content before picking up the nuts. Using the equilibrium relative humidity above a sealed container of nuts is one method of estimating moisture content since once the sample equilibrates with the air in the container, the relative humidity above the sample will give a reading of the water activity of the sample. A Rotronics Hygropalm 23 relative humidity moisture meter and HC2-C05 Mini Probe (http://www.rotronic-usa.com/shop.htm) was used to measure equilibrium relative humidity above samples of almonds taken from the orchard floor under various scenarios.

Figure 3 shows data from almonds that were shaken and then swept and windrowed about two days later and then left to dry about 7 days before picking them up. Moisture content was about 2% higher on nuts from the bottom of the windrow compared to those from the top (**Figure 3**). This is important since stockpiling nuts at constant, non-excessive moisture content is important to minimize possibility of conditions conducive to fungal growth. **Figure 4** shows the relationship between temperature and relative humidity in containers (same samples as in **Figure 3**) as temperature changes from approximately 50 degrees Fahrenheit to 100 degrees Fahrenheit. This figure points out the importance of temperature on the relative humidity (water activity) in the container.

Moisture content of nut sampled from different positions under the tree indicated about 2% higher moisture near the tree trunk as opposed to in the middle of the drive row in an orchard with about 60% midday canopy light interception (data not shown). Data from this orchard also suggested that as midday canopy light interception increased above 60%, average moisture content of nuts drying under the trees increased. These data agree with earlier data collected at our spur dynamics study showing orchard floor temperatures decreased as midday canopy light interception exceeded 60% (**Figure 6**). This suggests that high canopy light interception/high yielding orchards will require particular care to assure that nuts are adequately dry before the harvest operation begins. Since an orchard at 60% light interception can potentially produce a yield of about 3000 kernel pounds per acre, it is important that in orchards yielding at or above this level, particular care is given to assure than nuts have adequate time to dry on the orchard floor before they are picked up. We collected extensive orchard floor temperature data with our Mule mounted lightbar in the summer of 2009. See report for Lampinen et.al Development and Testing of a Mobile Platform for Measuring Canopy Light Interception and Water Stress in Almond, Project 09-HORT13-Lampinen) and these data will allow us to assess the variability in orchard floor temperatures and estimate the resulting variability in time for nuts to dry on the orchard floor.

Having a consistent temperature when measuring relative humidity above a nut sample is important. **Figure 5** shows the relationship between temperature and relative humidity in a container with almonds that were put into the container at the field temperature and then brought into a conditioned space for measurement. The nuts in the container took at least 20 minutes to come to temperature equilibrium with the room and during this time, temperature and relative humidity were changing quite rapidly. It would probably be best if growers took all nut samples into a constant temperature environment such as an air conditioned office for measurement. Samples should be allowed to equilibrate to room temperature before taking humidity measurements. Samples that are densely packed will require more time for equilibration than samples with good air circulation around them.

Preliminary results suggest that the white and white on black tarps should produce less day-to-night temperature fluctuations in the stockpile and this should be beneficial. Although temperatures are higher with a clear tarp, the higher temperature is associated with larger day to night temperature fluctuations. This is important since these temperature swings are associated with condensation of water on tarps, which can potentially cause problems for mold growth. Data from the nuts at the end of the 2009-2010 stockpiling period should clarify the benefits of the lower temperature fluctuations with the non-clear tarps.

References:

Kader, Adel A. 1996. "In-Plant Storage", pp. 274-277. In Almond Production Manual, Warren C. Micke, Technical Editor. University of California Division of Agriculture and Natural Resources, Publication 3364.

King, A.D.Jr., W.U. Halbrook, G. Fuller, and L.C. Whitehand. 1983. Almond nutmeat moisture and water activity and it influence on fungal flora and seed composition. J. Food Sci. 48: 615-617.

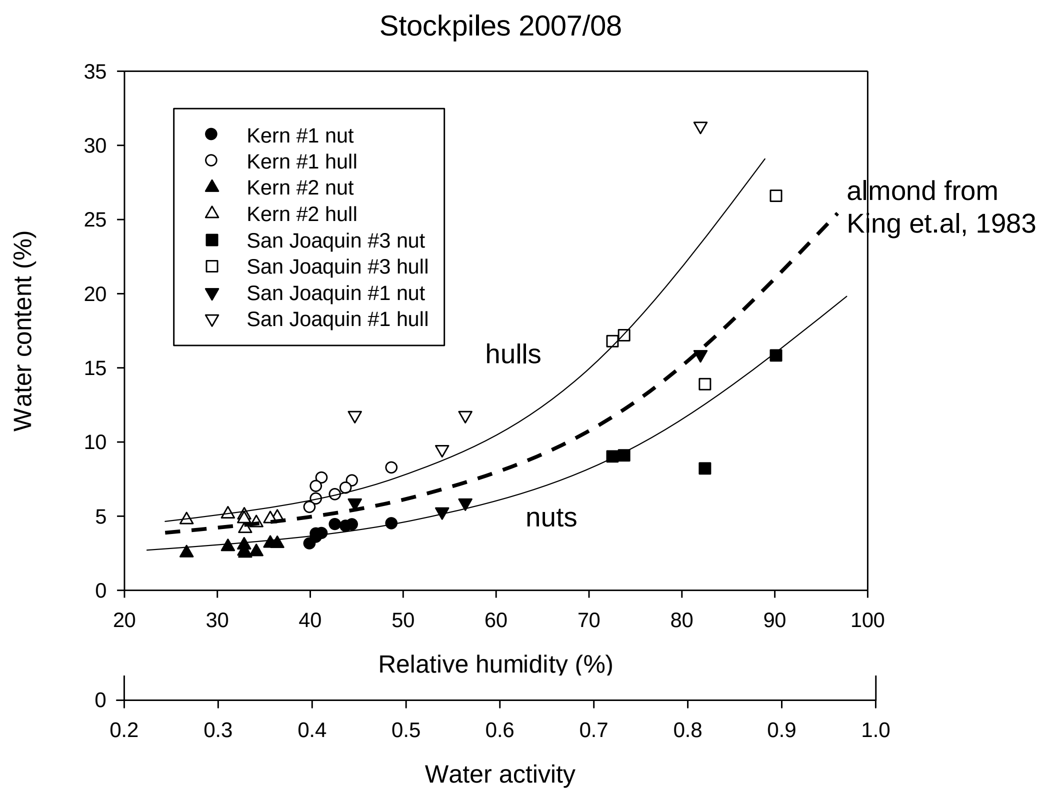


Figure 1. 2007/08 season: Relative humidity and water activity versus water content for nuts (including shell) and hulls from the Kern and San Joaquin County stockpiles. Data include cv. Nonpareil from Kern County as well as stockpile #1 and stockpile #3 from San Joaquin County. Dashed line is the approximate curve for almond kernels from King et. al, 1983.

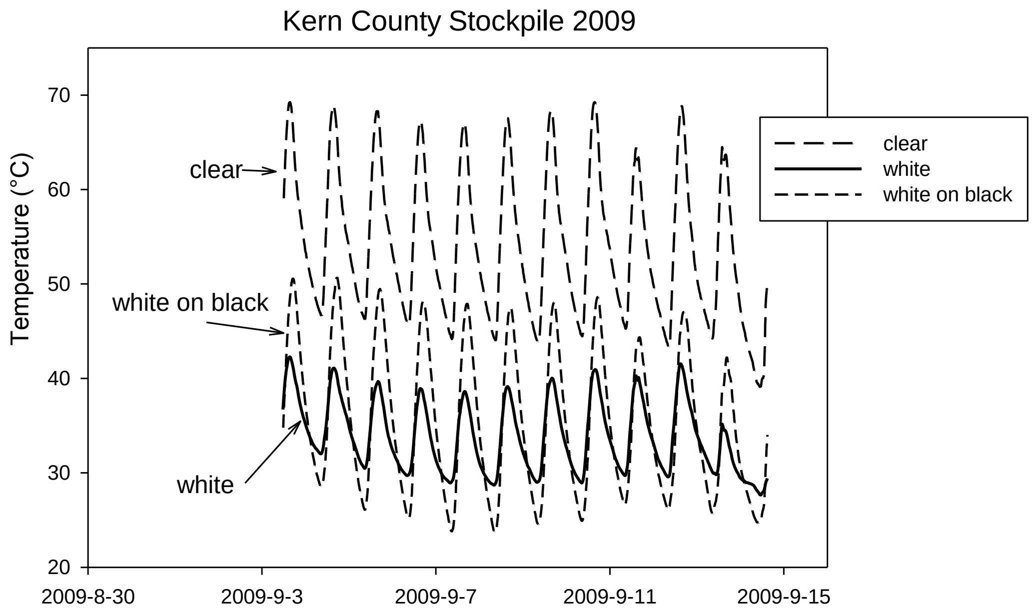
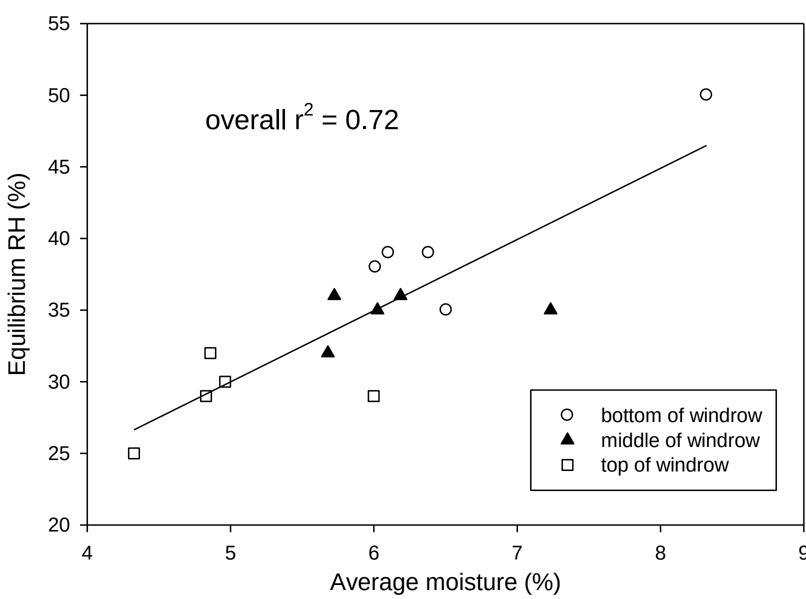


Figure 2. Temperature (in degrees Celsius) near top of stockpile under three different types of plastic cover in Kern County 2009. High temperatures under different tarp materials of 70, 50 and 40 degrees Celsius correspond to 158, 122, and 104 degrees Fahrenheit.



	sample humidity	sample %moisture
top	29 a	5.0 b
middle	34 b	6.2 a
bottom	40 c	6.7 a

Figure 3. Average moisture content versus equilibrium relative humidity in container of nuts from three depths in windrows from Colusa County Aldrich orchard. Nuts were windrowed about 2 days after shaking and samples were taken 7 days later on date of harvest. Samples were field run samples of nuts and hulls.

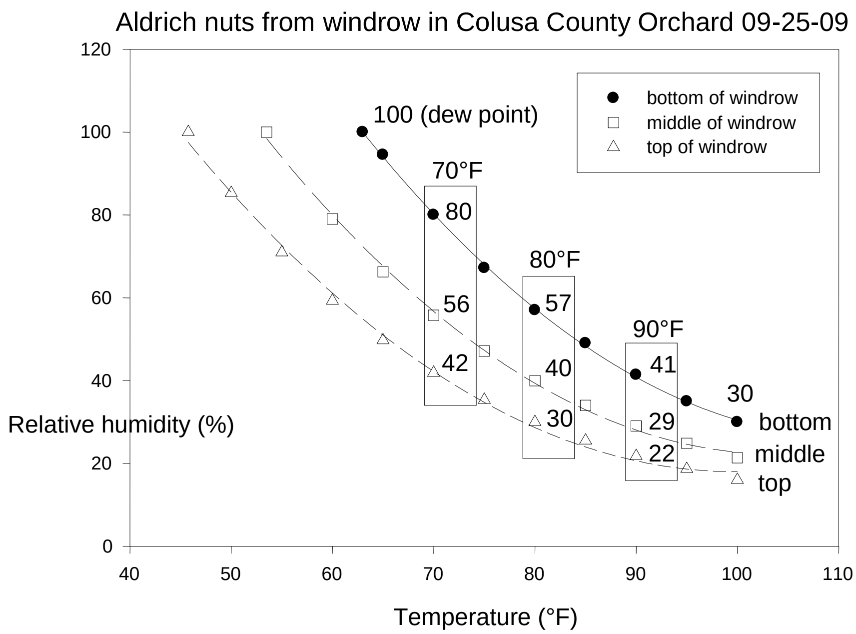


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Figure 4. Effect of temperature on equilibrium relative humidity for field run nuts and hulls from Figure 3.

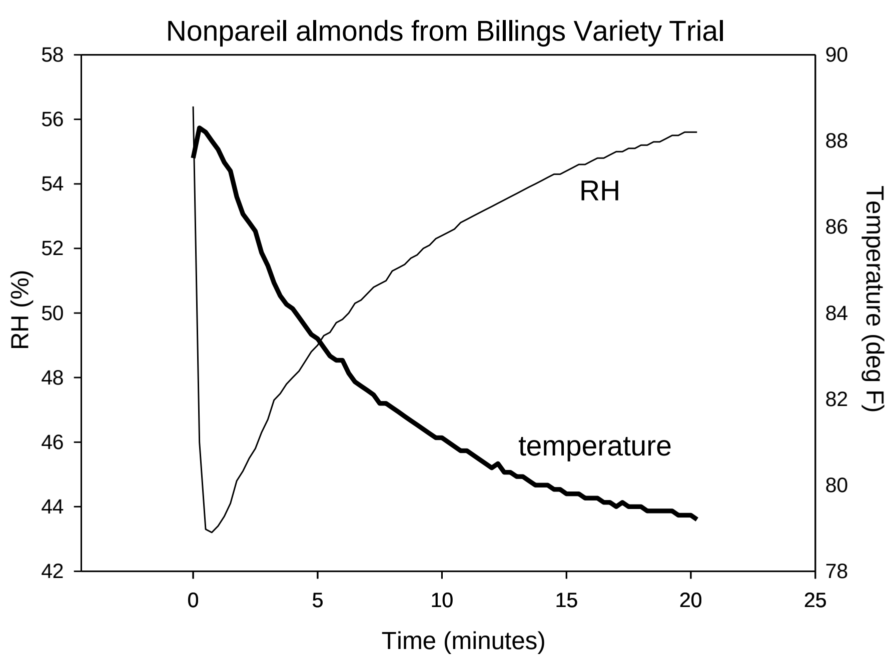

Figure 5. Temperature and relative humidity in container for a period of twenty minutes after enclosing field run samples of almond nuts and hulls. This figure points out the need to measure moisture content at a constant temperature and not shortly after taking them into a space with a large temperature difference from the sample temperature.

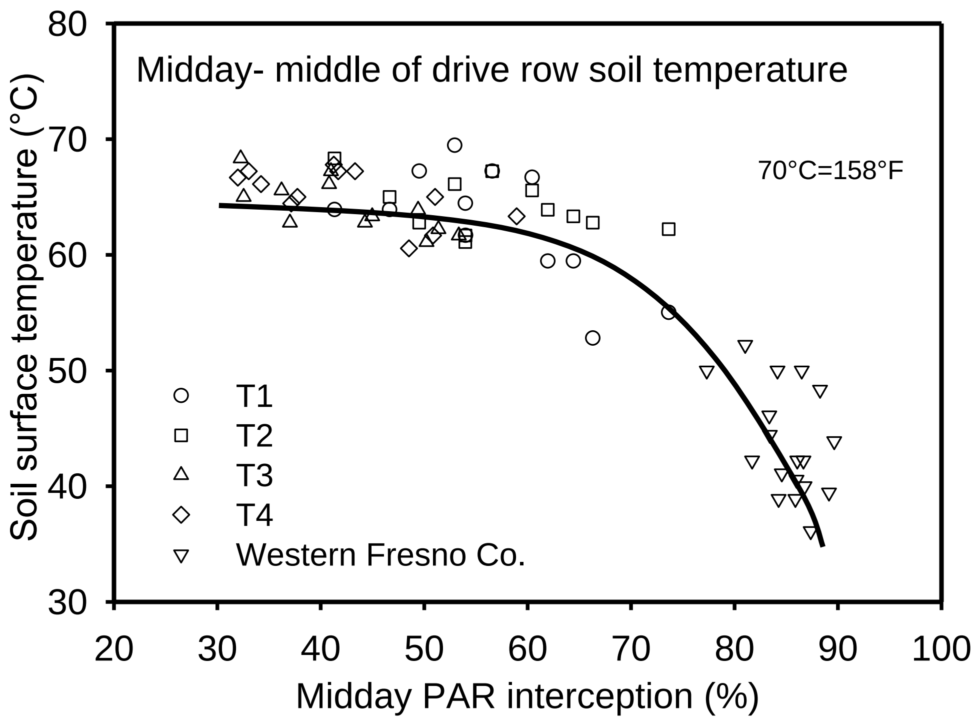

Figure 6. Middle of drive row temperature at midday at varying levels of canopy cover for spur dynamics trial 2003-2004 and hedgerow trial in Western Fresno County.