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Purpose of the research: To determine if air temperature variables exist that, in combination with previous-year yield, are useful in predicting yield of Kerman pistachio.





I asked a well-known farming operation if they would share some of their yield data with me, so that I could begin the statistical process that might help answer <u>if</u> air temperature variables can be useful in predicting future yield of Kerman pistachio. They graciously consented.

I obtained CPC yield data from three large orchards, some of which dated back to the mid-1980s.

In short, the objective of this research was to correlate the yield of these orchards with air-temperature records available from some nearby CIMIS stations.

Classes of temperature related variables 'tested' in the model -- to name a few:

- 1. Chill Portions (summed from Sept. 1 to Feb. 28)
- 2. Chill Hour accumulations for various calendar periods during the fall and winter
  - a. hours under 45° F. (measured from Nov. 15 to Feb. 15 or Dec. 15 to Jan. 31)
  - b. hours greater than 32 but less than 45° F.
  - c. Hours less than 32° F.
- 3. Heat unit accumulations (Growing Degree Days)s for various calendar periods during crop development using different base temperatures (45° F or 55° F)
- 4. Heat hour accumulations for various calendar periods during fall and winter
  - a. hours greater than 55° F. (measured from Nov. 15 to Feb. 15 or Dec. 15 to Jan. 31)
  - b. hours greater than 60° F.
  - c. hours greater than 65° F.
- 5. Heat hour accumulations during the bloom period
  - a. hours greater than 75° F.
  - b. hours greater than 80° F.
  - c. hours greater than 85° F.

The other major variable used in the model was "Previous Year Yield".

For an alternate bearing crop, such as pistachio, we would expect "Current Year Yield" to be negatively correlated with "Previous Year Yield".

That is, if we had a high yield in the previous year, we would expect this year's current yield to be low, and vice versa.

### Again,

The objective of this research is to find temperature variables during the year, that can help us predict our upcoming yield of Kerman pistachios at harvest.





I entered all of the information on the weather variables and previous year yield in a statistical multiple regression equation to see what would pop out as being <u>most</u> significant in predicting yield of <u>mature Kerman</u> pistachio in the <u>San Joaquin Valley</u> of California.

'Independent' variables (i.e. the regressors) that showed the most significance (based on F-to-enter and F-to-stay criteria used in the forward stepwise regression) in the combined data from the three orchards used in the research were as follows:

- 1. Yield of the previous-year harvest in lbs./acre (CPC yield), (best single predictor)
- 2. hourly air temperature accumulations above 65 °F from 15 Nov.– 15 Feb.
- 3. Hourly air temperature accumulations  $\geq$  45 °F &  $\leq$  60 °F from 15 Nov.–15 Feb.
- 4. hourly air temperature accumulations >80 °F from the time period 20 Mar.–25 Apr.,

I think these simple correlative findings is where this research has the most value. This research suggests that some weather variables appear to have some importance in predicting Kerman yield and, probably, worthy of further research.



Accumulated chill hours from November 15 to Feb. 15, appeared to be curvilinearly related to yield of Kerman pistachio. In the three orchards examined, high chill accumulations were associated with decreased yields.

Getting back to the four variables that appeared to have more value in predicting yield of pistachio;

- 1. Yield of the previous-year harvest in lbs./acre (CPC yield),
- 2. hourly air temperature accumulations above 65 °F from 15 Nov.–15 Feb.
- **3.** hourly air temperature accumulations  $\geq$  45 °F &  $\leq$  60 °F from 15 Nov.–15 Feb.
- 4. hourly air temperature accumulations >80 °F from the time period 20 Mar.-25 Apr.,

Variables 1, 2 and 4, listed above, were negatively correlated with yield. That is, when the values for these variables were high, yield was low. Thus, if there were a lot of hours with temperatures above 65 degrees F in the fall and winter, yield would be reduced and if during bloom, there were a lot of hours with temperatures above 80 degrees F, yield would be further reduced. However, temperatures greater than 45 and less than 60 °F were positively correlated with yield. More hours in this range increased yield.

Note that chill portion or chill hour accumulation variables were <u>not</u> as significant as those listed above.

The 'arrow of time' for crop production in a SJV pistachio orchard. Note that for variables in red, larger values decrease future yield, while larger values for variables in green increase future yield



### Also,

This research was aimed at associating weather variables with yield. No effort was made to associate air temperature variables with bloom timing, or adequacy of the pistachio "rest period".

As a result of this study, and with regard to pistachio in the <u>San</u> <u>Joaquin Valley</u>, I have tried to quit using the term "chilling" since I have never been able to do much "explaining" with the chilling models currently in use.

I have started to use the term "adequate fall and winter rest".

I, also, do not know what "adequate rest" entails but it appears to be a more general and a less suggestive term than 'chilling'. Using the regression model just described, with the significant variables described, you end up with an equation that can serve as a way to predict yield quantitatively.

So how do you use the regression equation to predict yield? The latest version of the model with explanatory documents is available at

http://cekern.ucanr.edu/Custom Program143/Kerman Pistachio Yield Estimator/ Note: In general, where growers have entered "old" data from previous years into the model it has been doing a fair job of predicting yield, except for the crop failure year of 2015.



Photo to the left shows a developing
cluster from the crop failure year of 2015
west side of Kern County, April 17,
2015.

The model has been fun to play with and I have been enjoying some of the grower feedback. I have even included new grower data in using the model.

Note: For best results the orchards should have a temperature data recorder close to the orchard that makes hourly measurements throughout the day. The trouble with CIMIS data are that there can be a lot of missing data.

#### What the model (in an Excel file) looks like before data is entered:

| Version 2, April 2017 Kerman Pistachio CPC Yield Prediction Worksheet - Authored by Craig Kallsen, UC Cooperative Extension (cekallsen@ucanr.edu)  |   |                           |   |                       |  |                     |   |                     |   |
|--|---|---------------------------|---|-----------------------|--|---------------------|---|---------------------|---|
| Required Inputs are 1. Previous Season Yield (Col. B); 2. Cumulatve no. of hours between 45 and 60 °F. between Nov. 15 and Feb. 15 (Col. D); 3. Cumulatve no. of hours less than 65 °F. between Nov. 15 and Feb. 15 (Col. F) and 4. Cumulative no. of hours greater than 80°F. between March 20 and April 25 (Col. H). |   |                           |   |                       |  |                     |   |                     |   |
| This model assumes that irrigation scheduline, crop nutrition, and pest control were above average and that the orchard is, at least, 15 years old. It also assumes that irrigation water quality is adequate.   |   |                           |   |                       |  |                     |   |                     |   |
| Enter values from your weather station in blue areas of file. Temperature data recorders should be set to record one temperature measurement per hour.   |   |                           |   |                       |  |                     |   |                     |   |
| Note that this model is based on a regression equation. Your values should be within the range specified in the column headings. Values not in the range are outside the data set upon which this model is based.  |   |                           |   |                       |  |                     |   |                     |   |
| There is room for 28   | eparate orchards on this file as written. | The bottom row, Row 39 ca | n be copied and pasted below to increase the n  | umber of orchards.    |  |                     |   |                     |   |
|  |   |                           |   |                       |  |                     |   |                     |   |
| Column A   | Column B                                  | Column C                  | Column D  | Column E              | Column F                               | Column G            | Column H                                | Column I            |   |
| Orchard ID   | Previous season Yield, Ibs/acre           | Column B limit test       | Nov. 15 - Feb. 15, no of hours >= 45 to <=60 F. | Column D limit test   | Nov. 15 - Feb. 15, no of hours > 65 F. | Column F limit test | Mar. 20 - April 25, no of hours > 80 F. | Column H limit test | Predicted CPC yield, lbs/acre           |
|  | Value must be between 100 and 7000        |                           | Value must be between 600 and 1700              |                       | Value must be between 0 and 330        |                     | Value must be between 0 and 130         |                     |   |
|  |   |                           |   |                       |  |                     |   |                     |   |
|  |   | Column B out of range     |   | Column D out of range |  | 0                   |   | 0                   | error - one or more inputs out of range |
|  |   | Column B out of range     |   | Column D out of range |  | 0                   |   | 0                   | error - one or more inputs out of range |
|  |   | Column B out of range     |   | Column D out of range |  | 0                   |   | 0                   | error - one or more inputs out of range |
|  |   | Column B out of range     |   | Column D out of range |  | 0                   |   | 0                   | error - one or more inputs out of range |
|  |   | Column B out of range     |   | Column D out of range |  | 0                   |   | 0                   | error - one or more inputs out of range |
|  |   | Column B out of range     |   | Column D out of range |  | 0                   |   | 0                   | error - one or more inputs out of range |
|  |   | Column B out of range     |   | Column D out of range |  | 0                   |   | 0                   | error - one or more inputs out of range |
|  |   | Column B out of range     |   | Column D out of range |  | 0                   |   | 0                   | error - one or more inputs out of range |
|  |   | Column B out of range     |   | Column D out of range |  | 0                   |   | 0                   | error - one or more inputs out of range |
|  |   | Column B out of range     |   | Column D out of range |  | 0                   |   | 0                   | error - one or more inputs out of range |
|  |   | Column B out of range     |   | Column D out of range |  | 0                   |   | 0                   | error - one or more inputs out of range |
|  |   | Column B out of range     |   | Column D out of range |  | 0                   |   | 0                   | error - one or more inputs out of range |
|  |   | Column B out of range     |   | Column D out of range |  | 0                   |   | 0                   | error - one or more inputs out of range |
|  |   | Column B out of range     |   | Column D out of range |  | 0                   |   | 0                   | error - one or more inputs out of range |
|  |   | Column B out of range     |   | Column D out of range |  | 0                   |   | 0                   | error - one or more inputs out of range |

#### Just enter data in the blue areas – one line for each orchard.

## Detail of the blank Excel Spreadsheet – Showing just Columns A, B and C. The rest of the spreadsheet is similar.

| Column A   | Column B                           | Column C              |
|------------|------------------------------------|-----------------------|
| Orchard ID | Previous season Yield, Ibs/acre    | Column B limit test   |
|            | Value must be between 100 and 7000 |                       |
|            |                                    |                       |
|            |                                    | Column B out of range |
|            |                                    | Column B out of range |
|            |                                    | Column B out of range |
|            |                                    | Column B out of range |
|            |                                    | Column B out of range |
|            |                                    | Column B out of range |
|            |                                    | Column B out of range |

The 'arrow of time' for crop production in a SJV pistachio orchard. Note that for variables in red, larger values decrease future yield, while larger values for variables in green increase future yield



### Results from the model once data is entered

| Version 2, April 2017 Kerman Pistachio CPC Yield Prediction Worksheet - Authored by Craig Kallsen, UC Cooperative Extension (cekallsen@ucanr.edu)   |   |                              |  |   |  |                     |   |                     |   |
|---|---|------------------------------|--|---|--|---------------------|---|---------------------|---|
| Required Inputs are 1. Previous Season Yield (Col. B); 2. Cumulatve no. of hours between 45 and 60° F. between Nov. 15 and Feb. 15 (Col. D); 3. Cumulatve no. of hours less than 65° F. between Nov. 15 and Feb. 15 (Col. F) and 4. Cumulative no. of hours greater than 80° F. between March 20 and April 25 (Col. H). |   |                              |  |   |  |                     |   |                     |   |
| This model assumes t  | hat irrigation scheduline, crop nutrition | , and pest control were abov | ve average and that the orchard is, at least, 15 y | ears old. It also assumes that irrigation | on water quality is adequate.          |                     |   |                     |   |
| Enter values from you   | r weather station in blue areas of file.  | Temperature data recorders   | s should be set to record one temperature mea      | surement per hour.                        |  |                     |   |                     |   |
| Note that this model i  | s based on a regression equation. Your    | values should be within the  | range specified in the column headings. Valu       | ies not in the range are outside the da   | ata set upon which this model is based |                     |   |                     |   |
| There is room for 28 separate orchards on this file as written. The bottom row, Row 39 can be copied and pasted below to increase the number of orchards.   |   |                              |  |   |  |                     |   |                     |   |
|   |   |                              |  |   |  |                     |   |                     |   |
| Column A  | Column B                                  | Column C                     | Column D   | Column E                                  | Column F                               | Column G            | Column H                                | Column I            |   |
| Orchard ID  | Previous season Yield, lbs/acre           | Column B limit test          | Nov. 15 - Feb. 15, no of hours >= 45 to <=60 F.    | Column D limit test                       | Nov. 15 - Feb. 15, no of hours > 65 F. | Column F limit test | Mar. 20 - April 25, no of hours > 80 F. | Column H limit test | Predicted CPC yield, lbs/acre           |
|   | Value must be between 100 and 7000        |                              | Value must be between 600 and 1700                 |   | Value must be between 0 and 330        |                     | Value must be between 0 and 130         |                     |   |
|   |   |                              |  |   |  |                     |   |                     |   |
| West block 17A  | 250                                       | 250                          | 1200   | 1200                                      | 67                                     | 67                  | 55                                      | 55                  | 5066                                    |
| West block 17B  | 5000                                      | 5000                         | 987  | 987                                       | 200                                    | 200                 | 80                                      | 80                  | 120                                     |
| East Block 13F  | 5000                                      | 5000                         | 1400   | 1400                                      | 85                                     | 85                  | 20                                      | 20                  | 2984                                    |
| East Block 12C  | 2500                                      | 2500                         | 1250   | 1250                                      | 300                                    | 300                 | 100                                     | 100                 | 1878                                    |
|   |   | Column B out of range        |  | Column D out of range                     |  | 0                   |   | 0                   | error - one or more inputs out of range |
|   |   | Column B out of range        |  | Column D out of range                     |  | 0                   |   | 0                   | error - one or more inputs out of range |

As a grower, you could use this model as a test of your ground and your farming practices. If your yields are substantially below what the model predicts year-in and year-out, perhaps there are ways to improve your production practices. The original data set from three orchards contained 80 data points from three orchards, with some yearly data dating back to the mid-1980s. Two of these orchards were on P. atlantica rootstock, which were chosen because they suffered less replanting than many orchards on these rootstocks, and because old maximum yield data were comparable to new yield data for these same orchards.

An interested grower supplied me with 40 (20 for 2015 and 20 for 2016) new data points for Kerman orchards 15 years or older for the years 2015 and 2016 (the crop failure year and recovery year). The original regression equation did not have any data from 2016.

So to see what would happen, I entered the grower's 2015 data into the existing model.

For the year prior to his harvest in 2015, this grower that gave me the additional 40 data points, measured and summed the following model-related temperatures using data from his ranch recorder:

hours  $\geq$  45 °F &  $\leq$  60 °F from Nov. 15 – Feb. 15  $\rightarrow$  1245 hours > than 65 F. from Nov. 15 – Feb. 15  $\rightarrow$  168 Hours > than 80 F. from 20 Mar.–25 Apr.,  $\rightarrow$  51

And, of course, he had his <u>previous yield</u> figures as well. He had all the data for 2015, that he needed to run the model by April 26 to predict his yield in September.

| Predicted yield by model for | Actual yield data for Fresno | Ranch IDs |  |  |
|------------------------------|------------------------------|-----------|--|--|
| orchards of Fresno grower    | grower                       |           |  |  |
|                              |                              |           |  |  |
| 2248                         | 293                          | 18-3 (96) |  |  |
| 1181                         | 395                          | 17-4      |  |  |
| 2420                         | 633                          | 17-1      |  |  |
| 2212                         | 372                          | 17-3      |  |  |
| 2156                         | 324                          | 17-2      |  |  |
| 2339                         | 393                          | 16-1      |  |  |
| 2464                         | 842                          | 21-4      |  |  |
| 2428                         | 771                          | 20-3      |  |  |
| 2424                         | 514                          | 20-4      |  |  |
| 2675                         | 630                          | 20-2      |  |  |
| 809                          | 447                          | 35-2 (99) |  |  |
| 445                          | 387                          | 36-1      |  |  |
| 28                           | 210                          | 36-2      |  |  |
| 604                          | 196                          | 36-3      |  |  |
| 2944                         | 2523                         | 26-1 (00) |  |  |
| 2499                         | 2769                         | 26-2      |  |  |
| 2846                         | 2719                         | 26-4      |  |  |
| 454                          | 207                          | 35-1      |  |  |
| 757                          | 443                          | 35-3      |  |  |
| 2378                         | 2547                         | 36-4      |  |  |
| 2712                         | 228                          | 15-1      |  |  |

Based on actual yield data and temperature variables for <u>crop failure</u> year of 2015.

| Predicted yield by model for | Actual yield data for Fresno | Ranch IDs |  |
|------------------------------|------------------------------|-----------|--|
| orchards of Fresno grower    | grower                       |           |  |
|                              |                              |           |  |
| 2248                         | 293                          | 18-3 (96) |  |
| 1181                         | 395                          | 17-4      |  |
| 2420                         | 633                          | 17-1      |  |
| 2212                         | 372                          | 17-3      |  |
| 2156                         | 324                          | 17-2      |  |
| 2339                         | 393                          | 16-1      |  |
| 2464                         | 842                          | 21-4      |  |
| 2428                         | 771                          | 20-3      |  |
| 2424                         | 514                          | 20-4      |  |
| 2675                         | 630                          | 20-2      |  |
| 809                          | 447                          | 35-2 (99) |  |
| 445                          | 387                          | 36-1      |  |
| 28                           | 210                          | 36-2      |  |
| 604                          | 196                          | 36-3      |  |
| 2944                         | 2523                         | 26-1 (00) |  |
| 2499                         | 2769                         | 26-2      |  |
| 2846                         | 2719                         | 26-4      |  |
| 454                          | 207                          | 35-1      |  |
| 757                          | 443                          | 35-3      |  |
| 2378                         | 2547                         | 36-4      |  |
| 2712                         | 228                          | 15-1      |  |

Note that the models for 2015, when it misses, almost always overestimates the yield that should have been obtained for this grower's data. This suggests to me that something unusual and deleterious happened in many orchards in 2015 that is not being 'accounted for' in the model and that, probably, cannot be accounted for in a model of this type. You can only bend polynomial functions so far.

## So let's go back and look at the map of the ranch this data came from.



Information was redacted to protect information of the grower.

Areas in green are seven blocks of 15+ year-old trees where the model did a poor job of predicting yields.

Areas in blue are 10 blocks where the model did a fair to good job of predicting yield in 2015.

No other blocks in this large ranch (areas whited out) are pistachios or are pistachios too young to be included in the model.

What is different about the green areas that resulted in the model predicting yields so differently? Numbers in black or silver are elevations in feet above sea level. The model is useful in that it gives you additional information to start asking these kind of questions. From my observations, it appears that when we have a high accumulation of heat in the flower buds during the fall and winter that something physiological happens within the bud. Dr. Zwieniecki (UC Davis) has shown that respiration increases with warm winter temperatures and stored starch in the bud is used up during the winter so no carbohydrate is available to fuel normal flower bud development in the spring. Or perhaps, the buds are "damaged" in some way by the heat. Perhaps high heat negatively affects other hormonal messaging within the bud which regulates normal flower development in the spring.



Excess solar radiation in the grove during the normal "rest period" for the tree, appears to affect flowering in the spring. The south side of the tree – the side that is most likely to receive excess, unshaded radiation from the sun, often demonstrates poor flowering and leaf push in years with hot day-time fall and winter temperatures. I was asked by an organizer of this meeting to discuss the use of petroleum oils to reduce the effect of winters with low chill/high heating. In general, oil has been applied in late January through the end of February for this purpose.

### So:

What about the use of February-applied oil to mitigate the effect of low winter chilling of high-winter heating on pistachio yield?

The <u>Australian pistachio industry</u>, which isn't very large, are enthusiastic supporters of the use of oil during years they perceive to be chill deficient. <u>For those that want to read about the relevant use of oil to mitigate low chill</u> <u>in the SJV the following two publications should be reviewed:</u>

Beede, B., D. Rose, A. Howe, H. Tutschulte, M. Barber and C. Kramer. 2002. Effect of
Orchex 692 and Volck horticultural mineral oils applied by air and ground on breaking
dormancy in pistachio. <u>California Pistachio Industry – Annual Report Year 2001-2002</u>. Pgs.
89-90. California Pistachio Commission. Fresno, Calif.

Beede, B., C. Nichols, B. Lahorn, T. Firkins, Z. Heath, K. Beinhorn, M. Barber and D. Aguire.
2003. Growth, yield and nut quality responses in a commercial pistachio orchard from dormant applied horticultural mineral oil (sixth year report). <u>California Pistachio Industry – Annual Report Year 2002-2003</u>. Pgs. 104-106. California Pistachio Commission. Fresno, Calif. 104-106.

From my personal observations of the use of oil in pistachio over the past 15 years or so, including two replicated tests using oil during the crop failure years of 2015 and the following year, I do not know what to think about the use of oil to mitigate "low-chill" years.

<u>First</u>, oil is not registered for this purpose.

<u>Second</u>, based on the results of this model discussed in this presentation, warm winter temperatures during fall and winter appear to reduce yield more than lack of chill (although seasons with warmer fall and winter temperatures do correlate positively with reduced chill).

Thirdly, from my personal observation, oil appears to advance flowering in the spring, regardless of the amount of winter chilling/heating received by the trees.

These points suggest to me that oil works "outside" the tree's physiological response to insufficient "chilling" or excessive winter "heating".

It appears to work more like a 'stress'-related plant growth regulator.

I think the most beneficial use of winter-applied petroleum oil is for the express purpose of advancing bloom, when it is applied during winters with low heating, 'normal' heating, and in winters with slightly elevated winter heating.

UC Farm Advisor Bob Beede has shown that oil will advance Kerman harvest by up to a week to help spread out the industrywide harvest season by getting more product to the processors earlier avoiding the 'crunch' when most 'Kerman' nuts mature. Oil, also appears to concentrate bloom over a shorter time span, which results in more similar nut maturity across the tree and the orchard, and which makes for more uniform nut removal from the tree at harvest.

Thus there may be less need for a second shake.

Based on some results from the crop-failure year of 2015, I would be hesitant to use oil in seasons with extremely high winter heating, as seasons like this tends to desynchronize the bloom of 'Kerman' and its pollinizing male 'Peters'.

### 2015 harvest season



Above – Oil treated male tree showing buds in March that have not yet bloomed (no pollen yet).



Above – Oil treated female tree in which the flowers are close to full bloom, taken on same day in the same orchard as male picture on the left.

# High winter heating, also appears to interfere with normal flower development and bloom, that oil is unlikely to overcome.



North (shaded) side of oil-treated tree (winter of 2014-15)

South side of oil-treated tree, taken the same day

## Petroleum oil <u>is</u> registered to control some soft scale insects in pistachio.

Read and follow the label directions on any petroleum oil product to make sure it is registered for use in pistachio. A number of petroleum oil products are registered for control of soft scale insects in pistachio (such as European fruit lecanium, frosted scale and black scale). European fruit lecanium is the most common scale pest. Foliar applications are typically made from mid-December to mid-February when immature scale are on the move. Good spray coverage is essential and many scale are in the upper canopy.

Scale location in the tree depends on species and season and even winter month. A good time to look for scale is during pruning operations when wood from high in the canopy is pruned and is laying on the ground.



The winter spray timing is most effective in that it target the immature stage when young scale are active and before they enter the 'rubber' stage in which they are more difficult to kill.

Read and follow all label directions carefully.





## Location: Visalia Convention Center Registration: ('google': pistachio short course) http://ucanr.edu/sites/PistachioShortCourse/

Kallsen, C.E. 2017. Temperature-related variables associated with yield of 'Kerman' pistachio in the San Joaquin Valley of California. HortScience: 52:598-605.