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OUTCROSSING IN AVOCADO: IS THERE A RELATIONSHIP TO FRUIT YIELD?

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In recent years, avocado growers in southern California have moved toward growing a single variety, Hass. This has resulted in the removal of trees of other varieties from the avocado grove. With these changes, there has been an observed decline in avocado fruit production. Is the cause of lower fruit numbers due to the higher degree of self-pollination? Or, looking at the situation at a different angle, is the absence of outcrossing causing a reduction in fruit numbers?

To examine the decrease in fruit numbers, our approach was to analyze the relationship between outcrossing and fruit yield. The questions addressed were fourfold. 1) What was the amount of outcrossing occurring in a Hass grove when a tree of another variety was serving as a pollen source? 2) Did a correlation exist between the degree of outcrossing and fruit numbers on the Hass tree? 3) Did distance have an effect on outcrossing? Did Hass trees located close to the pollen source show different amounts of outcrossing and fruit numbers than trees located further away? 4) Did climates of the different regions in southern California have differing effects on the amount of outcrossing?

Experimental sites were chosen within privately owned groves around southern California, based oh the criteria of

1) an isolated group of Hass trees with 2) a tree or trees of another avocado variety nearby potentially serving as a pollen source. This project concentrated on Bacon, Fuerte, or Zutano as the pollen sources.

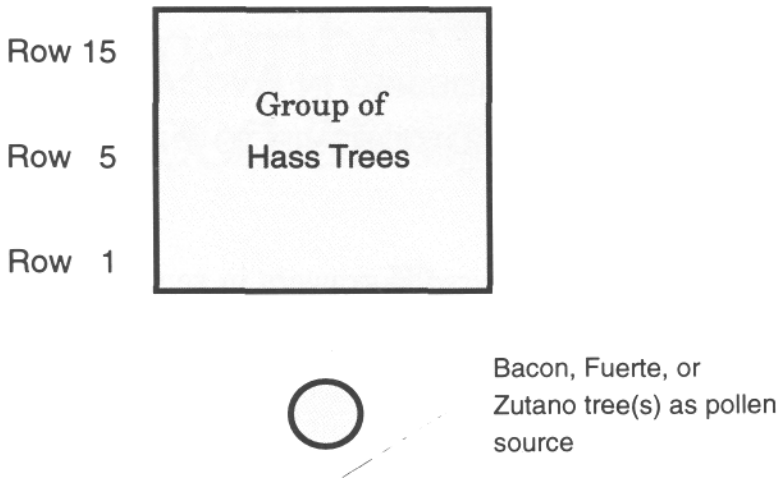


Figure 1. *General experimental plot design.*

Figure 1 shows the general experimental plot design where two Hass trees were selected from each of one, five, and fifteen rows away from the pollen source. From each of these six trees, the total number of fruit was counted and twenty fruit were collected. The embryos of collected fruit represent the outcome of a pollination event. With DNA extracted from the Hass embryo DNA and molecular markers uniquely identifying each of the pollen sources (Bacon, Fuerte, and Zutano), a molecular-based technique could both determine if an outcrossing event had occurred producing the Hass fruit, and which pollen source (Bacon, Fuerte, Zutano) provided the pollen.

On a larger scale, the effect of outcrossing in different climatic regions, inland and coastal, was also taken into consideration. Following the criteria of an isolated Hass grove with Bacon, Fuerte, or Zutano serving as pollen source, three privately owned groves, one for each of the pollen sources, were chosen in the Temecula area to represent an inland region. For the coastal region, three groves in Ventura, one for each of the pollen sources, and one grove in Santa Barbara with two sites—one for Bacon and one for Fuerte— were selected. Figure 2 shows the general strategy of the project. Table 1 shows the general location of the groves.

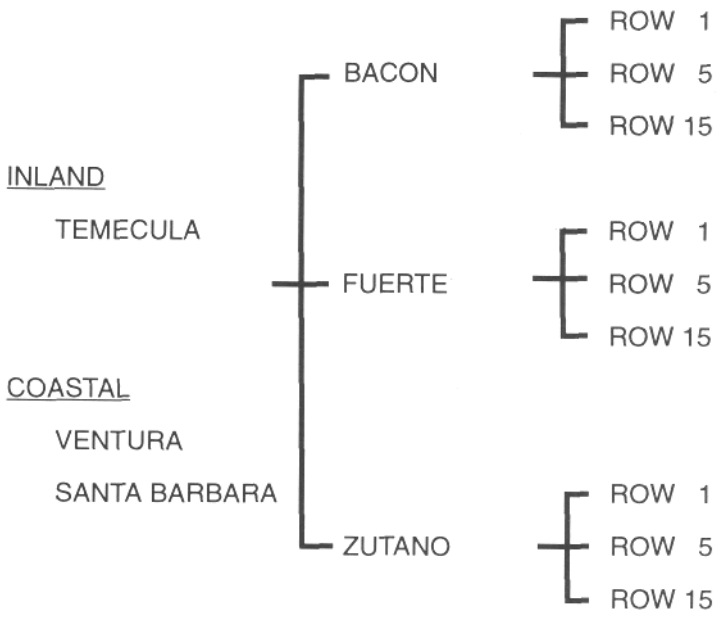
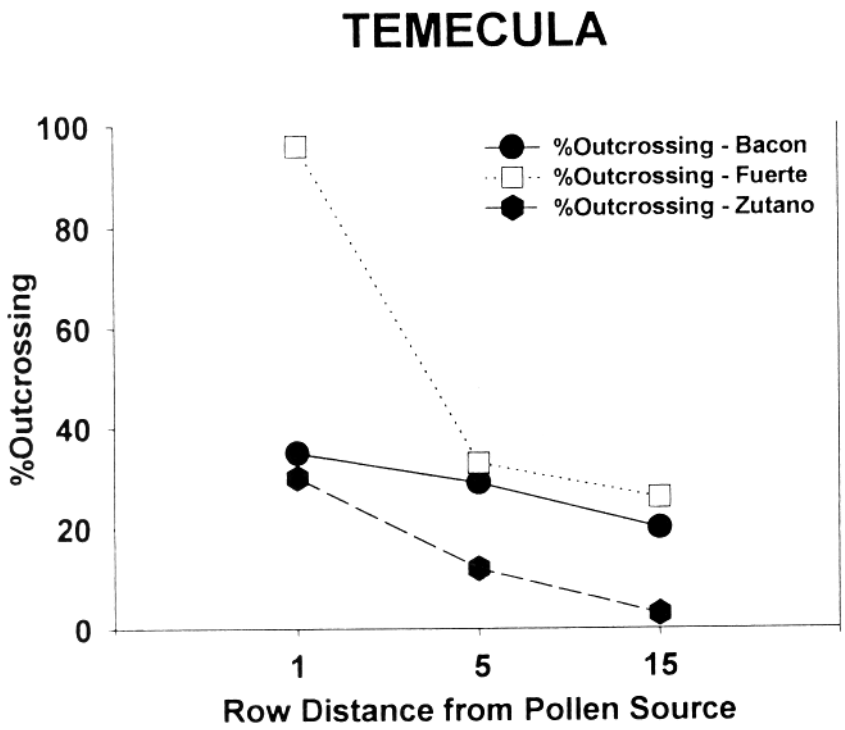


Figure 2. *Design strategy for the outcrossing project. (Note that Santa Barbara has only two sites, one for Bacon and one for Fuerte.)*

Table 1. *Location of groves where avocado collections were done*

Location	Pollen Source	Grove
Temecula	Bacon	Kanning Ranch
	Fuerte	On El Prado Road
	Zutano	On El Prado Road
Ventura County	Bacon	Saticoy
	Fuerte	Santa Paula
	Zutano	Santa Clara
Santa Barbara County	Bacon	Goleta
	Fuerte	Goleta

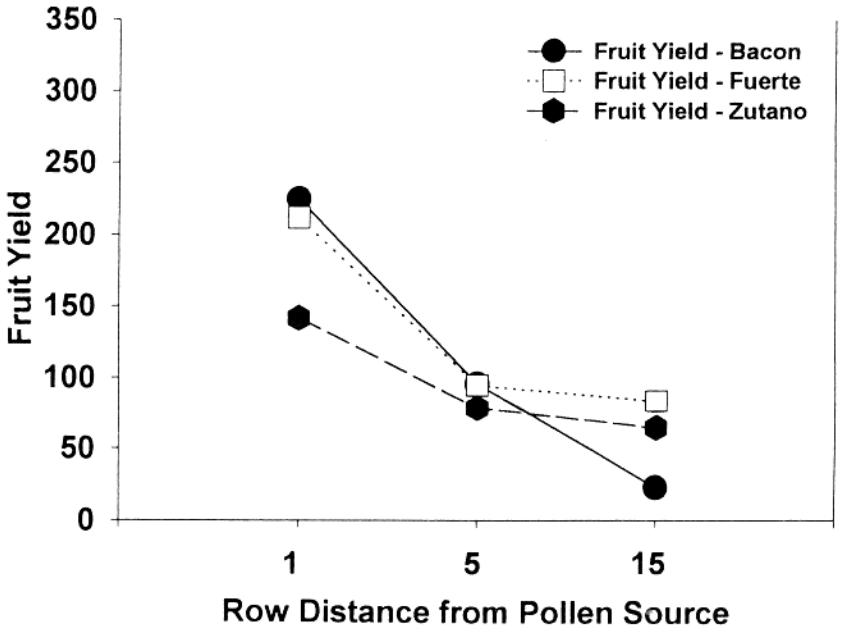
RESULTS



Graphs 1 (above) and 2 (following). *Graphs show data for the inland region, Temecula. Graph 1 shows the data points for outcrossing.*

For Graphs 1 to 7, each data point is an average for the two Hass trees in each of row 1, 5, or 15, for the three years of collection, 1993, 1994, and 1995. Data for the last year of the collection, 1996, are currently being assayed. For each Hass tree, percent outcrossing was calculated by the following formula:

$$\frac{\text{number of outcrossing events detected in the 20 Hass DNA embryos}}{\text{total number of fruit analyzed.}}$$



Graph 2. *This graph shows the data point for fruit yield. Each data point is an average for the two Hass trees in each of Rows 1, 5, 15 for the three years of collection: 1993, 1994, and 1995*.

INLAND REGIONS

Graphs 1 and 2 show the data for the inland region of Temecula. Graph 1 shows the data points for the amount of outcrossing detected and which of the three varieties, Bacon (represented by circles), Fuerte (represented by squares), and Zutano (represented by hexagons) contributed the pollen. The vertical axis on graph 1 represents the scale for percent outcrossing. Graph 2 shows the fruit yield counted on the two Hass trees of each row (rows 1,5, and 15). The vertical axis of this graph shows the scale for fruit yield. The horizontal axis, being the same for the two graphs, shows the number of rows the Hass trees are located from the pollen source.

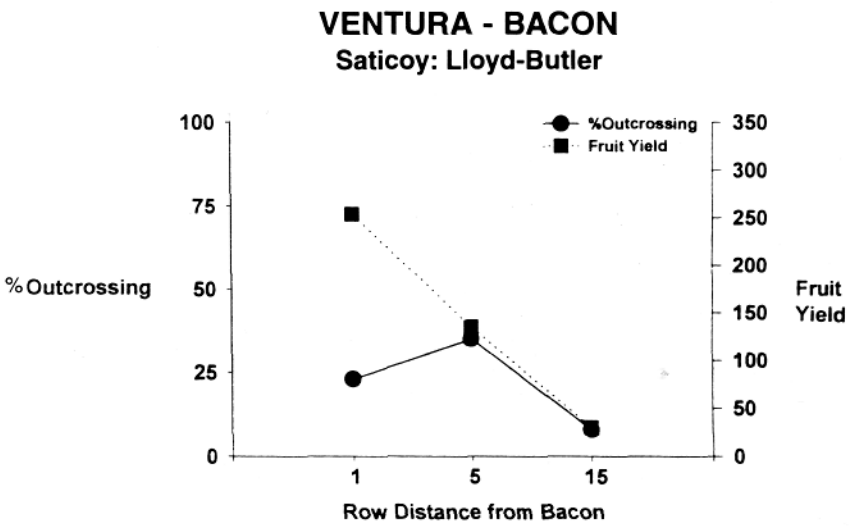
Predicted outcome for the results would be 1) the closer the Hass tree is located to the pollen source, the higher the amount of outcrossing because of the closer proximity to the pollen; 2) The outcrossing rate should decrease when examining Hass trees further from the pollen source; 3) if a correlation existed between outcrossing and fruit yield, fruit numbers would also be higher on trees located close to the pollen source and decrease on trees further from the pollen source. The data support these predictions. Outcrossing and fruit yield are at their highest value when Hass trees are closest to the pollen source, and the values decrease the further away the trees are from the pollen source. The conclusion that can be drawn for the inland region of Temecula is, in the presence of an alternate pollen source (Bacon, Fuerte, or Zutano), there is a correlation between outcrossing and fruit yield.

COASTAL REGIONS

For the coastal regions, the trends for outcrossing and fruit yield are not as clear. Each experimental site will be discussed on an individual basis. The graph for outcrossing and the graph for fruit yield have been combined to make one graph. The left vertical line represents one of the graphs, the scale for percent outcrossing with the circles showing the outcrossing data points. The right vertical line is the other graph, showing the scale for fruit yield with the squares representing the fruit yield data points. The horizontal line is shared by both graphs and shows the row distance of the Hass trees from the pollen source. Each data point is an average of the two Hass for the three years of collection.

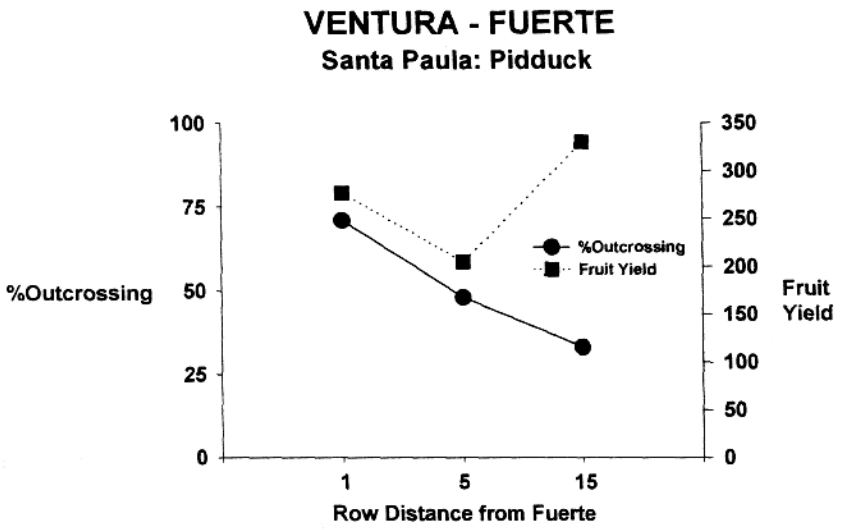
Graphs 3 through 7. The data for the coastal regions

Ventura and Santa Barbara are shown in the following five graphs. Each graph is the combination of two graphs—one for outcrossing, and the second for fruit yield. The left vertical line represents one of the graphs, the scale for percent outcrossing, with the circles showing the outcrossing data points. The right vertical line is the second graph, showing the scale for fruit yield, with the squares representing the fruit yield data points. The horizontal line is shared by both graphs and shows the row distance of the Hass trees from the pollen source. Each data point is an average of the two Hass for the three years of collection.



Graph 3. *Ventura: Bacon as pollen source*

The highest value for outcrossing was the Hass trees located closest to the Bacon tree. As expected, the fruit yield decreased when examining trees further from the Bacon pollen source. However, this trend is not seen with percent outcrossing. There is a decrease in outcrossing at row 1. There is no correlation between fruit yield and outcrossing at this site.



Graph 4. *Ventura: Fuerte as pollen source*

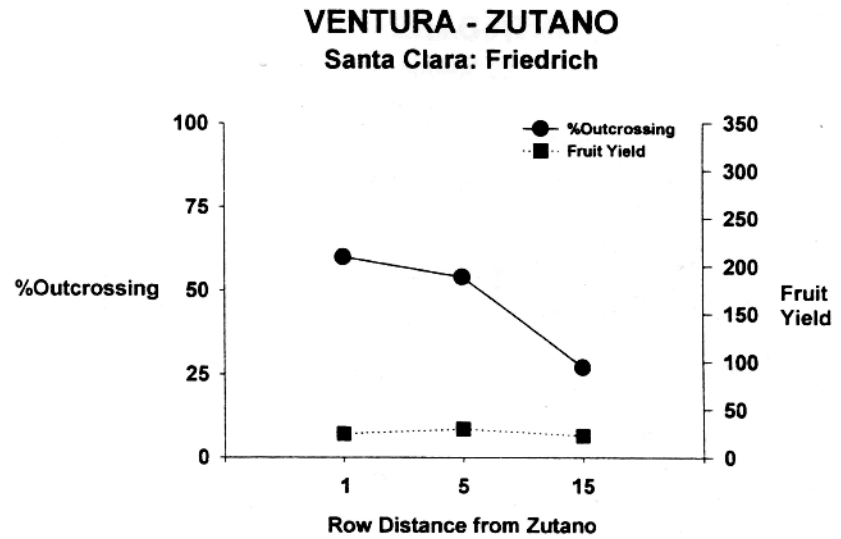
With Fuerte as the pollen source, there is a decrease in percent outcrossing when examining trees further from the Fuerte pollen source. But fruit yield increases at row 15. This demonstrates the inherent problem of working in private groves. It is known that a Bacon tree is located five rows away from the Hass trees in row 15. The pollen from this Bacon tree could be affecting fruit yield. To assess if Bacon pollen is a factor, we will analyze these fruit for the presence of Bacon pollen. These findings will be reported at a later date.

Graph 5. Ventura: Zutano as pollen source

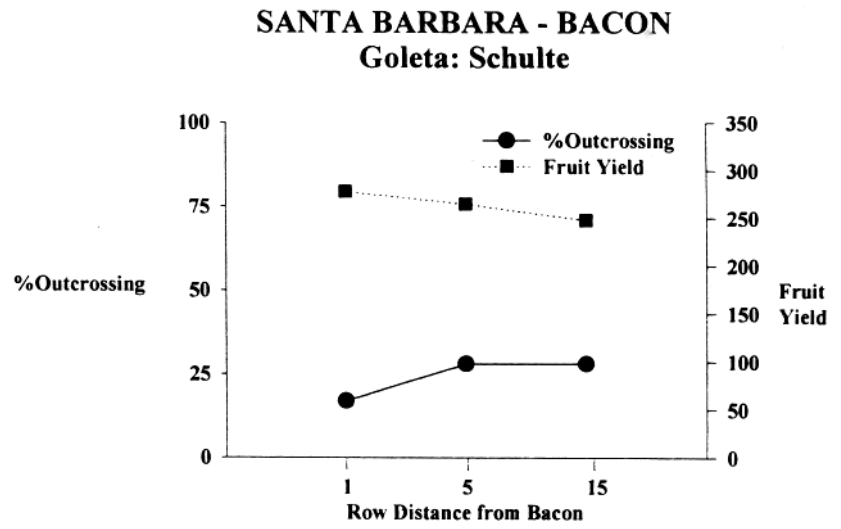
At this experimental site, fruit yields were low for the three years of collection. Valid comparisons between outcrossing and fruit yield could not be made.

Graph 6. Santa Barbara: Bacon as pollen source

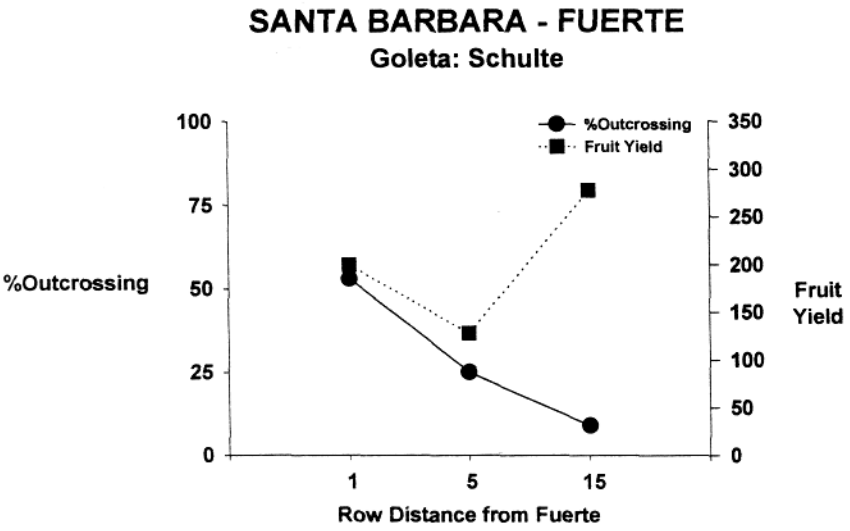
There is no correlation between outcrossing and fruit yield.



Graph 5. *Ventura: Zutano as pollen source*



Graph 6. *Santa Barbara: Bacon as pollen source*



Graph 7. *Santa Barbara: Fuerte as pollen source*

From the graph, outcrossing is decreasing when examining trees further from the pollen source. However, fruit yield does not show the same trend. There is a sharp increase in fruit yield at row 15. Therefore, no correlation exists between percent outcrossing and fruit yield.

DISCUSSION

With the trend toward Hass monoculture in southern California, there has been an observed decline in fruit yield. The question arises whether the absence of cross pollination may be the cause of lower fruit numbers. We addressed this problem by investigating: 1) the degree of outcrossing occurring in the presence of another variety

(Bacon, Fuerte, and Zutano) serving as a pollen source; 2) the existence of a correlation between outcrossing and fruit yield; 3) the effect of climate on outcrossing. This last point can be determined by comparing results from inland and coastal regions.)

In the inland region of Temecula, a correlation exists between utcrossing and fruit yield for Hass trees in the presence of the three pollen sources: Bacon, Fuerte, and Zutano. The closer the Hass tree was located to the pollen source, the higher the degree of outcrossing and, in turn, the higher the number of fruit. Examining Hass trees further from the pollen source, there is a noticed decrease in the amount of outcrossing and fruit yield.

In the coastal regions of Ventura and Santa Barbara, the correlation between outcrossing and fruit yield was not as clear. Inherent problems exist when working in privately owned groves. It is not possible to control the presence of trees of other varieties outside the experimental site. The contribution of pollen from these trees could have an effect on fruit production.

In coastal regions, a second confounding factor is the effect of low temperatures during time of bloom (Bringhurst, 1952;

Peterson, 1956; Bergh and Whitsell, 1974). Low temperature can Cause poor pollen tube growth (Sedgley, 1977; Sedgley and Annells, 1981), hus lowering fruit yield in years when temperatures during time of bloom are lower than 60°F.

We will analyze the outcrossing/fruit yield data with temperature data for the four years of collection. We propose to analyze a number of three-day spans where temperatures were above 60°F to ask whether there is a correlation with outcrossing and fruit yield. These data will be presented at a later date.

Based on three years of data, the conclusions we can make are:

1) With the inland region of Temecula, there is a clear correlation between outcrossing and fruit yield when an alternate pollen source (Bacon, Fuerte, or Zutano) is present.

2. With the coastal regions of Santa Barbara and Ventura, the correlation between outcrossing and fruit yield is not clear. Factors such as the presence of other pollen sources in the grove and the possible effect of temperature during time of bloom will be further investigated.

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