

THE CALIFORNIA CROSS POLLINATION EXPERIMENT – A PROGRESS REPORT ON THE INFLUENCE OF POLLINIZER VARIETY AND PROXIMITY ON 'HASS' YIELD

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SUMMARY

Preliminary results from a pollinizer trial in Oxnard California are reported. Yield data collected from 2002 – 2005 suggest that the presence of pollinizer varieties in close proximity enhance the total number of fruit harvested from 'Hass'. The influence of pollinizers on yield diminishes as the distance from the pollinizer variety increases. Differences were detected between pollinizer varieties in terms of influencing 'Hass' yield. The highest 'Hass' yields were observed when 'Fuerte', 'Zutano' and 'SirPrize' were used as the pollinizer. The lowest cumulative yield was observed when 'Harvest', an A-Flower type was used. Small but significant differences have been detected in percent dry weight, fruit and seed length/width ratio and seed size.

Key words: pollinizer, yield, proximity

INTRODUCTION

Research dating back to early avocado research has highlighted the importance of understanding the nuances of avocado flowering. However a review of the literature (Gustafson and Bergh, 1966, Davenport, 1986) also shows that this topic still remains controversial regarding the need for pollinators (the vector for pollination), pollinizers (complementary varieties) and strategic placement of pollinizer varieties (Arpaia and Hofshi, 2004, Arpaia et al 2004, Davenport, 2004).

Niroydy (1922) was the first to describe synchronous dichogamy in the avocado, that is, the occurrence of distinctive female and male stages within an individual flower. Stout in 1923 described this behavior in detail for California avocado varieties and then later for Florida cultivars (1933). He also categorized avocado varieties into A- and B-Flower types. Under normal weather conditions, A-Flower types open as female flowers in the morning of one day; close at mid-day then open in the male stage the following afternoon. The B-Flower types open female in the afternoon of day 1 and reopen in the male stage the following morning. Stout and Savage (1925) were the first to suggest the possible benefit of interplanting varieties with complementary flowering types to enhance overall avocado productivity. Research suggesting the need for a vector to carry the pollen from one flower to the next was also established by pioneer avocado researchers. Clark (1923) in the first caging studies of avocado showed the need for pollen-transferring agent such as honey bees although his caging research also demonstrated that considerable differences

may exist between avocado varieties with respect to the need for cross pollination (Clark 1923, 1924 and Clark and Clark, 1926).

It is generally believed that due to the avocado flowering cycle (synchronous dichogamy) that cross-pollination is favored. The question still remains as to what pollinizer to use. Previous research has demonstrated that certain varieties are more effective pollinizers (Israel, Ettinger; Chile, Edranol; California, Zutano, Fuerte and Bacon (Bergh and Garber, 1964; Degani et al, 1997; Gandolfo, 1995; Kobayashi et al, 2000)). Three important factors to consider when selecting a pollinizer variety for 'Hass' are the synchrony of bloom during the spring, that is having the complementary varieties flowering during the same period, the timing of the pollinizer's flowering cycle to the 'Hass' flowering cycle during the day and the spatial placement of the pollinizer relative to 'Hass'. Bergh et al (1966) reported an approximate 40% increase in 'Fuerte' yield when trees were adjacent to 'Topa Topa' over an 8 year period. The authors report no significant difference beyond the first row. They concluded that the most probable explanation for the observed yield increases was cross pollination. The question of course is what is the vector moving the pollen from flower to flower and is that vector's movement limited. Work by Ish Am (personal communication) indicates that honeybees typically visit 1 to 2 trees in close proximity to each other; thus the potential for cross pollination is most likely limited to trees near the pollinizer variety.

In 1999 a trial was established to examine the possible influence of several B-flower types on 'Hass' yield. The goal of the trial is to test the impact of yield of 3 advanced selections from the UC, Riverside varietal breeding program that were B-Flower types ('SirPrize', BL667 ('Nobel') and BL516 ('Marvel') (Witney and Martin, 1995). These three selections also produced black fruit with fruit from 'Nobel' and 'Marvel' appearing 'Hass-like'. The 'SirPrize' was patented and released by UC in 1996. A secondary objective has been to revisit the topic of pollinizer proximity and 'Hass' yield. Reported below are preliminary data from the study.

MATERIALS AND METHODS

The trial is located on the Oxnard Plain (Ventura County, CA). The approximate 12 HA site is divided into 6 experimental blocks. Each block consists of either 24 or 25 rows. There are 20 trees in each row. All rows run in a north-south direction. The field is bordered on the east and west side by very tall (>10 m) eucalyptus windbreaks. The field is also divided in half longitudinally by a poplar windbreak (>10 m height, between rows 25 and 26). When the plot was established lemon orchards bordered the plot on all sides. The lemons have been removed over the course of the study and currently the north, east and south side of the study plot are bordered by strawberries and the west side of the block is bordered by avocados. In 2 of the blocks the trees are spaced 5.2 x 7.6 m. These two blocks are located on the north side of the field and are separated from the remaining 4 blocks by an 8-m wide farm road. The trees in the remaining 4 blocks are spaced at 3.8 x 7.6 m. All trees are irrigated using low-volume sprinklers and irrigation is applied based on water demand (generally once per week during the spring, summer and fall months). By the 4th year, the 'Hass' trees were approximately 4.5 to 5-m tall. At this time, the trees were topped mechanically to about 4 meters. The trees have been topped to this height annually since that time just after harvest is complete (generally March to April during bloom). The tree topping leaves the trees with a flat top. The trees have

also been pruned on several occasions to remove interior dead wood and to reduce canopy width between the rows. This pruning has occurred at the same time as the mechanical topping. The trees are fertilized using standard horticultural practices.

Honeybees are introduced each spring for pollination purposes (6 to 10 hives/HA). Hives are generally placed along the farm road separating experimental blocks 1 and 2 from blocks 4 – 6. Bees have also been placed some years along the margin of the field as well as along the eucalyptus windbreaks. Honeybees are introduced generally in February and remain in the field through June. The ‘Hass’ trees may begin flowering as early as December in some years and generally flower through the early part of June. Peak bloom usually occurs from mid-March through mid-May. In 2001 dataloggers were placed in the field to record air temperature as well as relative humidity (Onset Computer Corporation, Pocasset, Mass.).

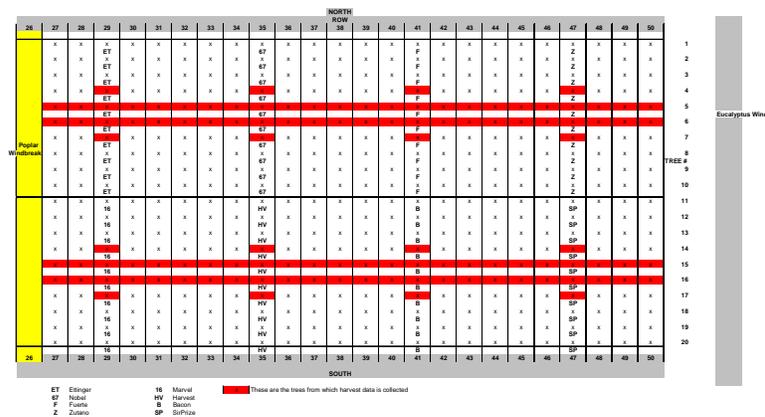


Figure 1. One replicate block illustrating the field layout of the experiment. The red lines are the field transects representing trees from which yield data are collected.

In spring, 1998 ‘Hass’ trees on Duke 7 rootstock were planted. Approximately a year later, the pollinizer varieties (also on Duke 7 rootstock) were planted (Figure 1). The following pollinizers are included: ‘Bacon’, ‘Ettinger’, ‘Zutano’, ‘Fuerte’, ‘Marvel’, ‘Nobel’, ‘SirPrize’ and ‘Harvest’. All pollinizers are of the B-flower type with the exception of ‘Harvest’ which is an A-flower type. Additionally there are trees of ‘Lamb Hass’, an A-Flower type, between the 2 northernmost blocks and the remainder of the field. The ‘Lamb Hass’ trees are in sets of 10 trees inter-set in the pollinizer rows (every 6th row). There are 6 replicates of each pollinizer with the exception of ‘Nobel’ which there are 3. In the place of ‘Nobel’ in the remaining blocks, the pollinizer ‘SirPrize’ was substituted. The pollinizer trees are set between ‘Hass’ trees on the west side of the row. Ten trees of each pollinizer are included in each block.

Harvesting transects are established across each block. There are a total of 694 data trees. In all rows, yield is collected from the fifth and sixth tree within a pollinizer group. In the pollinizer rows (the rows in which the pollinizer varieties are inter-set) yield is also collected from the fourth and seventh tree, thus yield data has been collected from the middle of each experimental block to minimize possible border effects (Figure 1). All fruit from each tree are harvested at one time. Fruit harvests occur in the Spring, generally in March or April of each year. Total weight and fruit

number per tree is recorded. In 2001, 3 of the replicate blocks were harvested. In 2002-2005 all replicate blocks were harvested. Data presented below is from the 2002-2005 time period.

In 2004 and 2005, 8-fruit samples of ‘Hass’ (approximately size 48) were taken from the pollinizer rows for each pollinizer type. Fruit maturity was determined on individual fruit using the Hofshi Coring machine (Arpaia et al, 2001). Fruit length and width were also recorded. In 2005 seed weight was also recorded.

Data reported here was analyzed using CoStat version 6.204 (CoHort Software, Monterey, CA, USA, <http://www.cohort.com>). Mean separation was calculated using the Student-Newman-Keuls Test with a significance level of 0.05.

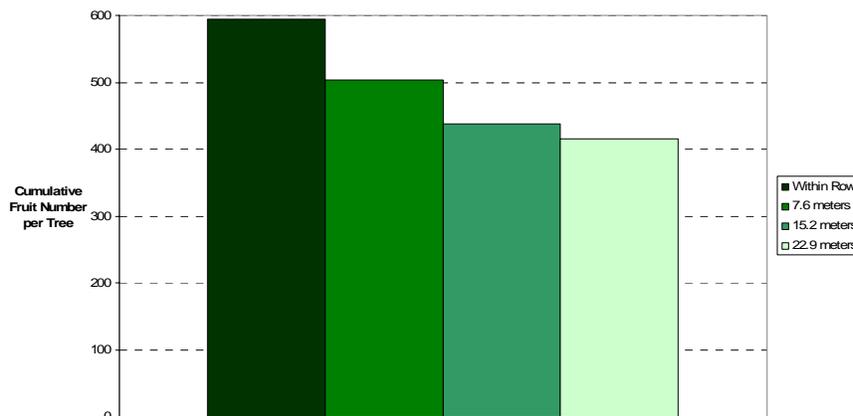


Figure 2. Distance from pollinizers influences the cumulative yield of ‘Hass’. Data collected from 2002-2005 near Oxnard, CA.

Table 1. Fruit count per tree as a function of distance from a pollinizer. Mean separation using Student-Newman-Keuls Test, $P < 0.05$ (n.s. = not significant).

Distance from Pollinizer (meters)	Year				Cumulative Number
	2002	2003	2004	2005	
0.0	179 n.s.	30 a	342 a	45 n.s.	595 a
7.6	180	22 ab	248 b	52	503 b
15.2	153	16 b	213 c	55	438 c
22.9	151	21 ab	197 c	46	415 c

RESULTS AND DISCUSSION

Fruit Number and Proximity to Pollinizers. There is an overall statistical difference in cumulative fruit numbers harvested from the experimental site (Figure 2, Table 1). The highest cumulative fruit numbers were obtained from the ‘Hass’ trees in the pollinizer rows. Trees one row away (7.6 m) had the second highest yields. There was no significant difference detected between the second or third row (15.2 and 22.9 m away, respectively). The significance in fruit numbers harvested is related to the high yield obtained in 2004. In this year, significant differences due to distance

from pollinizer were also detected (Figure 3, Table 2). These results differ slightly from Bergh et al (1966). In that study the authors report it was only when ‘Fuerte’ trees were adjacent to ‘Topa Topa’ did one see a significant increase in yield. The results from this study suggest that proximity to the pollinizer variety can influence yield. A difference between the two studies could be related to the presence of honeybees in the present study and differences in environmental conditions during bloom. The present study site tends to be cooler during flowering than the site used by Bergh et al (1966).

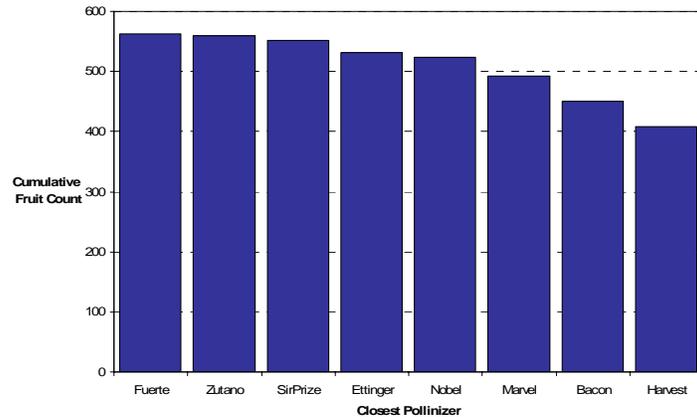


Figure 3. Cumulative ‘Hass’ fruit number (2002-2005) as a function of pollinizer variety. Data pooled across rows 0 – 2 (0 – 15.2 m). Data collected near Oxnard, CA.

Table 2. ‘Hass’ fruit count per tree as influenced by pollinizer variety and distance from the pollinizer. Mean separation using Student-Newman-Keuls Test, $P < 0.05$ (n.s. = not significant).

Closest Pollinizer	Distance from Pollinizer (meters)			
	0	7.6	15.2	All Rows
Bacon	547 ab	432 n.s.	373 n.s.	451 bc
Ettinger	619 ab	544	429	531 ab
Fuerte	675 a	492	523	563 a
Harvest	480 b	444	304	409 c
Marvel	554 ab	495	423	492 abc
Nobel	540 ab	574	456	523 ab
SirPrize	668 a	514	473	552 a
Zutano	616 ab	553	511	560 a

Fruit Characteristics as influenced by Pollinizer Variety. Average fruit weight was calculated by dividing the total number of fruit harvest by the total weight per tree. In 2002 and 2004 (high production years) there were significant differences in average fruit weight related to pollinizer variety. Not surprisingly, in the treatments which had higher fruit numbers, average fruit weight was smaller. Average fruit weight across all pollinizers and distances ranged from 205 to 228 g in 2002, 222-263 g in 2003, 207 to 230 g in 2004 and 282 – 296 g in 2005.

Table 3 presents the results of the dry weight measurements and compares the 2005 data with the data collected in a similar manner to 2004. Note that in both years 'Hass' fruit from the 'Nobel' pollinizer rows had the highest dry matter whereas the 'Hass' from the 'Marvel' pollinizer rows had the lowest. A difference between the 2 years of sampling is seen with 'Hass' fruit from the 'Zutano' pollinizer rows. In 2004 this sample had the second highest dry matter whereas in 2005 the dry weight is the second lowest. The 'Hass' trees in this experiment bloom for an extended period and these apparent differences in dry weight may be related to the timing of fruit set and synchrony with the pollinizer in terms of flowering and fruit set.

Table 3. Average 'Hass' dry weight for 2004 and 2005. Fruit harvested both years in April from pollinizer rows. Mean separation by LSD, P<0.05.

Pollinizer	2004		2005	
Bacon	25.34	ab	27.42	abc
Ettinger	25.30	abc	26.44	bc
Fuerte	24.80	bc	27.30	abc
Harvest	24.95	bc	28.06	ab
Marvel	24.45	c	25.88	c
Nobel	26.20	a	28.72	a
SirPrize	24.94	bc	26.90	abc
Zutano	26.08	a	25.92	c

Table 4 presents data collected both years for the fruit length/width ratio and the seed length/width ratio as well as the seed percentage for 2005. Note that in 2005 the 'Hass' fruit from the 'Fuerte' pollinizer row had a slightly more elongated fruit as compared to the 'Hass' fruit coming from the 'SirPrize' pollinizer row. There were no significant differences detected in 2004. The seed length/width varied between both years, however in both years 'Hass' fruit from the 'Fuerte' and 'Harvest' pollinizer rows had slightly more elongated seed.

Table 4. Average 'Hass' fruit length/width ratio, seed length/width ratio and percentage seed per fruit. Fruit harvested from pollinizer rows in April 2004 or 2005. Mean separation by LSD, P<0.05 (n.s. = not significant)

Closest Pollinizer	Fruit length/width ratio				Seed length/width ratio				2005 Seed % of fruit weight	
	2004		2005		2004		2005			
Bacon	1.29	n.s.	1.45	ab	1.13	bc	1.13	b	12.47	a
Marvel	1.40		1.47	ab	1.14	bc	1.16	ab	12.01	ab
Nobel	1.43		1.50	ab	1.15	abc	1.17	ab	12.09	ab
Ettinger	1.37		1.47	ab	1.11	c	1.15	ab	10.55	bc
Fuerte	1.39		1.52	a	1.19	a	1.20	a	9.91	c
Harvest	1.45		1.49	ab	1.18	ab	1.19	a	11.99	ab
SirPrize	1.37		1.42	b	1.15	bc	1.10	b	12.39	a
Zutano	1.37		1.46	ab	1.11	c	1.13	b	11.70	ab

In 2005 we were able to also ascertain the seed percentage of the total fruit weight. In this case, 'Hass' fruit from the 'Fuerte' pollinizer row had the smallest seeds and

fruit from either the 'Bacon' or 'SirPrize' pollinizer rows had the largest percent seed. These data suggest that out-crossing may be occurring and that pollen parent is influencing fruit shape and seed size. The occurrence of metaxenia has been previously reported for avocado (Degani et al, 1990; Gafni, 1984). A weakness of this study has been our inability to test for parentage of the 'Hass' fruit. In a companion project, Dr. T. L. Davenport is collecting paternity data using microsatellite markers. This data should help us to interpret these results.

CONCLUSION

The preliminary results from this study confirm the observations of Bergh et al (1966) that the use of pollinizers can enhance yield of avocado. These data also suggest that the choice of pollinizer variety may also be important. When selecting a pollinizer variety the following things should be considered:

1. Synchrony of flowering cycle with the 'Hass' flowering cycle and the response of each variety to temperature variances. It is well documented that each variety has its own temperature optimum for flowering (Sedgley and Annells, 1981; Sedgley and Grant, 1983)
2. Multiple pollinizers may give a better overlap with the 'Hass' bloom. Since there can be differences from year to year in terms of flowering time and intensity, it may be advisable to use multiple pollinizer varieties in the orchard.
3. Spatial placement of pollinizers; proximity does have an impact. For maximum impact each 'Hass' tree should be "seeing" a pollinizer tree (approximately 11% of trees).
4. Tree size and management considerations. In this trial, the 'Fuerte' and 'SirPrize' appear to give good results, however one must consider that these two varieties produce very large, spreading trees, something which may not be desirable. On the other hand 'Zutano' and 'Ettinger' produce more slender and upright trees. These may be easier to manage from a horticultural perspective.

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