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Enhancement of Avocado Productivity. Plant Improvement: Selection and Evaluation of Improved Varieties and Rootstocks

Continuing Project: Year 9 of 20

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Benefit to the Industry

This project will help to maintain and enhance the California avocado industry by introducing consistently heavier producing, high-quality avocado varieties, better pollinizer varieties, and improved rootstock hybrids. Increasing the genetic diversity of varieties will decrease the risk of major pest and disease invasions on a susceptible monoculture.

Objectives

A. To produce new avocado varieties, superior to 'Hass' in consistent productivity and postharvest fruit quality and marketability, with fruit of optimum maturity and size year-round. This includes determining the different cultural needs of each cultivar. Index trees for distribution for sunblotch viroid with assistance of Drs. Allan Dodds, and Deb Mathews.
B. To collaborate with other researchers worldwide in evaluating and exchanging promising plant material.
C. To collaborate with Dr. Douhan and Dr. Crowley on rootstock selection and evaluation for both root rot resistance and salinity tolerance.
D. Evaluate the potential of new and established cultivars (B flower types) for use as pollinizers in collaboration with Dr. Ben Faber and others as requested.
E. To maintain and improve the CAS variety block and the *Persea* germplasm block located at the UC South Coast Research and Extension Center.
F. To insure the timely and effective dissemination of information developed from this research program.

Summary

A. To produce new avocado varieties, superior to 'Hass' in consistent productivity and postharvest fruit quality and marketability, with fruit of optimum maturity and size year-round.

There are 2 components of this objective. The first is the continued monitoring of varieties from the Dr. B. Bergh/Gray Martin selection program. The second component is the new phase of scion selection. Activities for both components are summarized below.

Component 1. Continued monitoring of Bergh/Martin selections

Various field trials have been established to monitor the performance of a number of the Bergh/Martin selections. Several of the sites are now at the end of their allotted time period and after the final data are collected, those sites will be terminated. The following is a list of the cooperator trials we are maintaining and those sites to be terminated. In 2002 we installed data loggers to monitor air and soil temperature and relative humidity at all sites. We plan to use this data to help us assess the selection's response to low/high temperature when these events occur.

There are also additional plantings of the Bergh/Martin selections scattered throughout southern California. We periodically visit these sites to evaluate trees and discuss tree performance with the cooperators.

Topworked trials at Non-UC Sites

Santa Paula (Ventura County); topworked in 1998; 'GEM', 'Harvest', 'Sir Prize', 'RT5176', 'OA184', 'Marvel', 'Hass'; 10 replicates. Ending 2005.

De Luz (San Diego County); topworked in 1998; 'Lamb Hass', 'Sir Prize', 'GEM', 'Marvel', '5-552', 'Nobel', 'Hass', 'Harvest'; 10 replicates. Ending 2005.

De Luz (San Diego County); topworked in 1998; approximately 80 'GEM' trees divided roughly into 3 groups at the cooperator site. Ending 2005.

San Luis Obispo (San Luis Obispo County); topworked in 1998 (Trees suffered from freeze in 12/98 necessitating re-grafting of some selections in 1999; 'RT5176', 'Hass', 'Sir Prize', 'GEM', 'Harvest', 'OA184'; 9 replicates. Ending 2005.

Clonal trials at Non-UC Sites

Oxnard (Ventura County); planted in 1996; 'Lamb Hass', 'Sir Prize', 'GEM', 'OA184', 'Marvel', 'Nobel', 'Hass', 'Harvest'. (This trial was flooded in 1997 and many trees died due to this, however we are now working with the current owners to collect data from the trees which survived after the winter of 1997)

HTH Ranch (Ventura County); 'Lamb Hass', 'Marvel', 'GEM' and 'Hass' A non-replicated trial used for dry weights and fruit evaluation only.

Topworked trees at UC, Riverside Campus – ongoing; Replacement trees in Field 10.

Topworked trees at UC, South Coast Research and Extension Center (SCREC); Field 4 at the Center has topworked trees (variable number of replicates) from which we collect data. These trees were topworked onto seedling rootstock trees in 1994 – 1996.

San Joaquin Valley Variety Trial – 1999 at two sites (Porterville, Lindcove) with clonal trees (Thomas rootstock); 'Sir Prize' 'Lamb Hass', 'Harvest', 'GEM', 'Nobel', 'Marvel', 'Pinkerton', 'Fuerte', and 'Zutano'; 20 replicates per scion variety at each site. We had trouble with tree establishment for certain varieties, therefore surviving tree numbers varies with site and variety. In spring 2005, several trees at the Lindcove site collapsed. Subsequent testing revealed that collapse and subsequent tree death was due to *Phytophthora cinnamomi*. We have also had problems with certain varieties dropping fruit prior to harvest and this continued to be a problem in 2004-2005.; however we were able to collect a second season's

data on dry matter. We plan to collect a third and final year of dry matter data this upcoming year.

Yield data from Bergh/Martin selections. We have collected yield data for the seventh year from Field 4 at UC-SCREC (UC South Coast Research and Extension Center). Data collection for 2005 shows that for most varieties, this was an 'off' year (Figure 1). The '(variety as indicated by data) at this point has the largest cumulative yield over the seven year period. Comparing the coefficient of variation shows that there is tendency toward less extreme alternate bearing in 'GEM' (Figure 2; this is calculated by dividing the standard deviation by the mean and gives one an idea of the relative variation of the data for a particular variety).

We have not yet completed the fifth year of yield data from the Santa Paula site in Ventura County, the Righetti site near San Luis Obispo, nor the De Luz site in San Diego County. There is no yield information from the Oxnard site as the grove was inadvertently harvested before the data could be collected.

Fruit characteristics of Bergh/Martin selections. As an on-going process we are collecting fruit samples from all sites approximately every 4 to 5 weeks from winter through late fall. These fruit are evaluated using standard protocols for such characteristics as fruit shape, peel texture, peel color, flesh color, the percent seed, flesh and skin and skin thickness.

Seasonal dry matter content of Bergh/Martin selections. The trends in dry weight accumulation were similar to the trends observed in previous years. The general pattern for dry weight accumulations for each variety in 2005 is consistent with the 2000 – 2004 data presented previously. A comparison between dry weight accumulations between six maturity seasons for the 'GEM' variety is presented in Figure 3. This data is from the UC-SCREC site.

Bloom evaluation of Bergh/Martin selections. The bloom of spring 2005 was evaluated on the trees in the unreleased variety block at UC-SCREC. This is the fourth year of this type of data collection. Bloom was rated for intensity, and an estimate of the number of open flowers was made for each tree. This was done weekly throughout the bloom season. Figure 4 illustrates the relative timing of each variety over the 4 year period.

Release of Bergh/Martin selections. The UC Office of Technology Transfer obtained patents for two of the Bergh/Martin selections, 'GEM' (U.S. Plant Patent No. 14,239) and 'Harvest' (U.S. Plant Patent No. 14,238) effective October 14, 2003. We believe that 'GEM' has commercial potential for the California industry and wish to make this selection more widely available to growers. The 'Harvest', on the other hand, had been given by G. Martin to researchers in Spain, Israel and South Africa where there is interest in the variety from a commercial perspective. The UC Office of Technology Transfer is currently working on patents in various foreign countries that are interested in this material. Growers interested in these varieties can either contact M. L. Arpaia, D. Stottlemyer or Dr. William Tucker at the UC Office of Technology Transfer for more information.

Component 2. New Material for the Breeding Program

We are taking 2 approaches towards generating new material for the California industry. These approaches are the outcome of discussions with B. O. Bergh, U. Lavi (Avocado breeder, Volcani Institute, Israel) and A. W. Whiley (Australia). The first approach is to plant out seedlings from interesting maternal sources; this is done without any effort to control paternity. This approach

was suggested by U. Lavi. In spring 2000, we planted the first 217 seedlings from mixed maternal sources to provide material for the "next generation" of avocado selections using this approach. An additional 237 seedlings were planted out in 2002, 186 seedlings in 2003 and 244 seedlings in 2004. So far, 645 seedlings have been planted out in 2005 with another 300+ seedlings to be planted this fall. We anticipate an additional 350 seedlings will be planted out in spring 2005. Table 1 shows the maternal parents of the current seedling population planted at UC-SCREC.

Table 1. Open pollinated seedlings from varying maternal sources planted at the UC South Coast Research and Extension Center from 2000 to 2005.

Year Planted	Maternal Source												Total Planted
	5-552	Marvel	Nobel	GEM	Gwen	Lamb Hass	Bacon	SirPrize	Thille x GEM	GEM x Thille	Marvel x GEM	GEM x Marvel	
2000	32	90	37	39	14	5							217
2002		75	51	91		20							237
2003		50	25	41	55				15				186
2004	30	61	48	42	55							6	244
2005		60	73	99	23	60	3	17		179	12	113	645
Totals	**62**	**336**	**234**	**312**	**147**	**85**	**3**	**17**	**15**	**179**	**12**	**119**	**1531**

Note: The "Total Planted" per year may not always add up due to some trees with lost labels where the parents are "unknown."

Of the 217 trees planted in 2000, 86 have produced fruit and have been evaluated. Seven seedlings have been selected for further evaluation and have been topworked onto Duke7 rootstock at SCREC, and are also being propagated onto clonal rootstock material for further field evaluations. After the grafting was done, one additional seedling was flagged for further evaluation bringing the total number of interesting selections to 8. Two of these selections were selected for their sympodial growth habit; the other 6 were selected mainly on the basis of flavor.

Table 2. Isolation blocks established in 1999 – 2001.

Parents	Year established	Location
GEM x Marvel	1999 (topwork)	UC, Riverside
GEM x Thille	1999 (topwork)	UC, Riverside
Gwen x Gwen	2001 (clonal tree)	Nakamura, Ventura Co.
Lamb x GEM	2001 (clonal tree)	Nakamura, Ventura Co.
Lamb x Nobel	2001 (clonal tree)	Nakamura, Ventura Co.
Lamb x Thille	2001 (clonal tree)	Nakamura, Ventura Co.
Lamb x Reed	2001 (clonal tree)	Nakamura, Ventura Co.
Stewart x Reed	2001 (clonal tree)	Nakamura, Ventura Co.

In the second approach we have taken the more traditional approach of Dr. Bergh by establishing isolation plots in various locations. Table 2 lists the location, year established and selections in each isolation block. The potential parents were selected under consultation with Dr. Bergh. A

total of 305 seed were collected for germination from the isolation blocks and 864 from open-pollinated sources for a total of 1169 seeds to be germinated for the 2005-2006 season.

In June 2005, we asked Dr. Uri Lavi (fruit breeder including avocado from the Volcani Institute in Israel) and Dr. Jose Chaparro (citrus and stone fruit breeder from the University of Florida, Gainesville) to review our progress over the last 6 years. They made many useful suggestions for improvement of the program and helped us in developing strategies for the future. Their comments are available upon request to M. L. Arpaia.

Sunblotch Viroid indexing. One hundred twenty seven trees at the UC-SCREC were tested for the sunblotch viroid between October 1, 2004 and September 30, 2005. Of these trees, 11 tested positive for the Sunblotch Viroid and have been removed. All of the positive trees were in field 46 and represent our continuing effort to eliminate sunblotch from that field. In 2004, one positive tree was found in field 44. This was the first positive tree in that field and it was removed immediately. All surrounding trees were tested but found to be negative. Adjacent trees were tested again this year with no sign of the sunblotch viroid.

B. To collaborate with other researchers worldwide in evaluating and exchanging promising plant material.

Introduction of new germplasm. We have continued to plant out new varieties as they come out of quarantine. In August 2005, two Andes selections and Puebla were officially released from quarantine. The Andes selections are believed to be seedlings or bud sports of Hass and were selected in Chile by the Andes Nursery Association. This material came to California under a test agreement. We will plant these trees at UC South Coast REC and evaluating their potential for California. The Puebla, which is a heritage variety originating in California, was brought back to California in 2002 from the germplasm collection of the Catholic University of Valparaiso, Chile. With the aid of Dr. Ben Ya'acov, who confirmed the identity of the variety in Chile, we elected to bring this variety back to California for placement in the variety collection. Other Puebla trees in California are of uncertain identity and this introduction will aid us in identifying Puebla trees growing throughout southern California. Finally, two additional varieties of interest were brought in from Chile from the Andes Nursery Association (A.N.A.) in September 2004. This material is currently in quarantine. We plan to receive additional material from Chile in collaboration with Monica Castro and Claudia Fassio (Catholic University of Valparaiso, Chile) in spring 2006. This material will include the 'Isabel' a promising new selection which they believe is cold-hardy.

C. To collaborate with Dr. Douhan (Dept. of Plant Pathology, UCR), and Dr. Crowley on rootstock selection and evaluation for both root rot resistance and salinity tolerance.

We planted a new clonal rootstock trial at UC SCREC with Dr. Menge in spring 1999 and collected a fourth year of yield data from this plot in 2005. The 'Hass' and the 'Lamb Hass' are included in this trial on selected clonal rootstocks ('Hass' on Day, Duke7, Dusa, Evstro, G755A, Parida, PP4, Spencer, Thomas, Toro Canyon; 20 replicates 'Lamb Hass' on Day, Duke 7, Evstro, Thomas, Toro Canyon; 20 replicates).

We continue to collaborate with Dr. Crowley in his salinity research whenever possible and have assisted in the evaluation of a salinity/*Phytophthora* rootstock trial established in Santa Barbara using rootstocks from Dr. Menge's program, South Africa and Israel.

D. Evaluate the potential of new and established cultivars (B flower types) for use as pollinizers in collaboration with Dr. Ben Faber and others as requested.

In conjunction with Ben Faber we established a pollinizer site in Ventura County (Oxnard) in spring 1999. We are using funding from BARD (a collaborative effort with Drs. Arnon Dag and Sharoni Shafir (Israel) and Dr. Tom Davenport (University of Florida)) to collect floral data as well at this site as well as 2 other sites. Below is a preliminary discussion of our 4 years of yield data. We hope to collect 2 additional years of yield data before completing this portion of the project.

Fruit Number and Proximity to Pollinizers. There is an overall statistical difference in cumulative fruit numbers harvested from the experimental site (Figure 5, Table 3). The highest cumulative fruit numbers were obtained from the 'Hass' trees in the pollinizer rows. Trees one row away (7.6 m, 25 ft) had the second highest yields. There was no significant difference detected between the second or third row (15.2 and 22.9 m (50 and 75 ft) 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 (Table 3). 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).

Table 3. 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	

Fruit Number and Pollinizer Variety. Figure 6 and Table 4 present the cumulative fruit count results by pollinizer variety. Pollinizer variety had a significant impact on the fruit number within row, or when the pollinizer was adjacent to 'Hass', however there were no differences due to pollinizer variety as distance from the pollinizers increased. Even though there was no difference between pollinizer varieties 1 or 2 rows from the pollinizer trees, if all data across rows is combined, a statistical difference is detected. In this study, proximity to 'Fuerte' resulted

in the overall highest 'Hass' yields followed closely by 'Zutano' and 'SirPrize'. Kobayashi et al (2000) using genetic markers also reported enhanced 'Hass' yield when 'Fuerte' was in close proximity as compared to other B-Flower type avocado. They also report a proximity influence on fruit yield, higher yields closer to pollinizers.

Table 4. '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 5 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 6 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.

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.

Table 5. 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 6. 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

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.

E. To maintain and improve the CAS variety block and the *Persea* germplasm block located at the UC South Coast Research and Extension Center.

An accurate plot map has been generated for the CAS Variety Block at UC-SCREC. Any changes to the planting are being recorded in the master database maintained by David Stottlemyer. The UC-SCREC avocado volunteers have been instrumental in maintaining this

block. The volunteers graft several new and/or historical varieties on an on-going basis. Fields 44 and 46 have been maintained and kept in order through regular pruning and constant observation by both the lab personnel and the volunteer staff. In addition, the sprinkler lines in field 46 have been replaced and updated in coordination w/the SCREC personnel.

F. To insure the timely and effective dissemination of information developed from this research program.

The current avocado web site at: www.ucavo.ucr.edu has been on-line since June 1998. The site is periodically revised and updated with new information and photographs of different varieties. Leaf photographs showing both flush and mature leaves are currently being added to the web site with plans to add tree photographs as well. Questions sent via e-mail or forwarded from the California Avocado Commission are answered on an ongoing basis.

Figure 1. Variety trial yield data (average fruit count per tree) collected from Field 4 at the UC South Coast Research and Extension Center in Irvine, CA from 1999 – 2005. Trees were topworked onto seedling rootstock in 1994 – 1996.

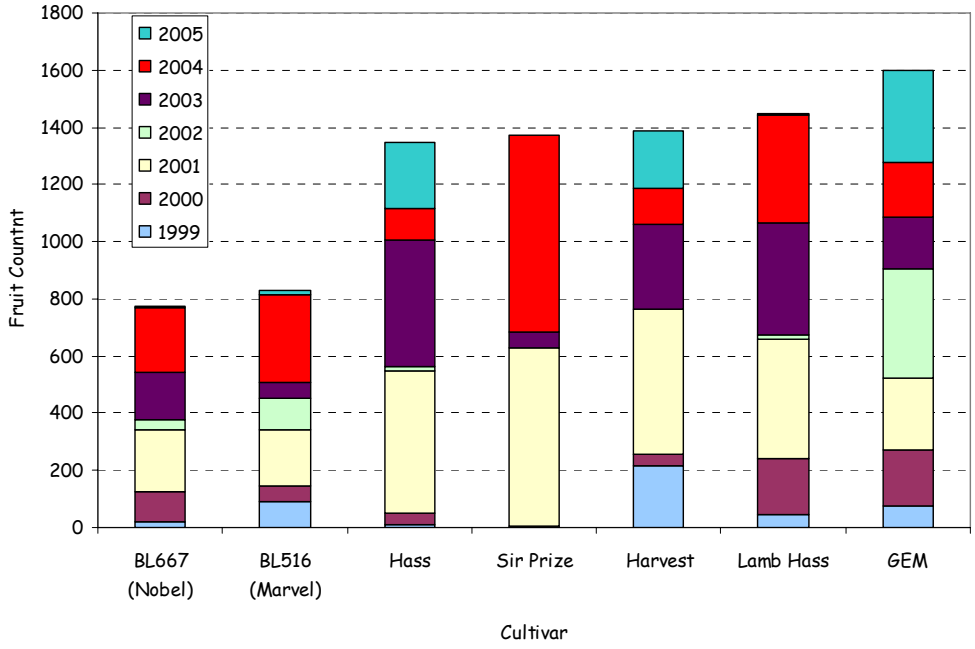

Figure 2. The Coefficient of Variation (%) in yield (fruit number) for each variety from Field 4 at the UC South Coast Research and Extension Center in Irvine, CA from 1999 – 2005. Yield data for 'Harvest' incomplete as of September 2005.

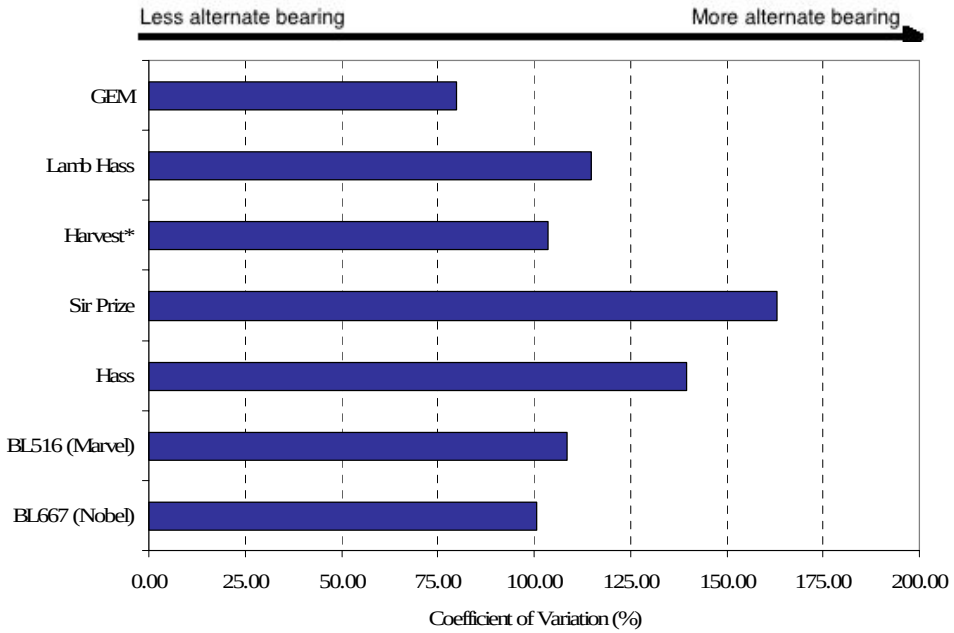

Figure 3. Seasonal trends (2000 – 2005) in dry weight accumulation for GEM from January through October at the UC South Coast Research and Extension Center, Irvine, CA.

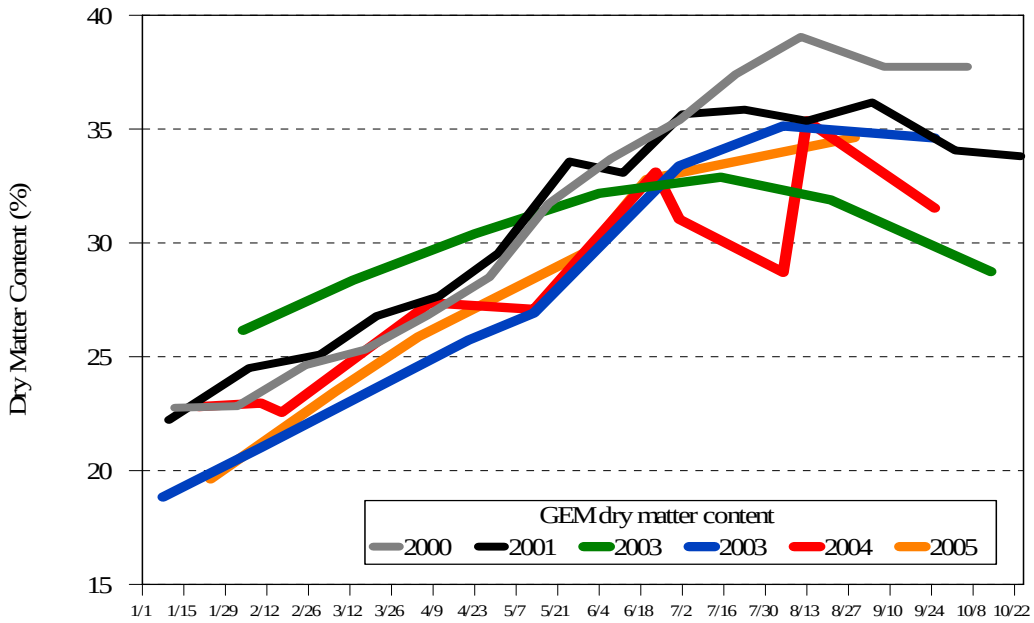

Figure 4. Comparison of average bloom dates for two years for all varieties from February through May at the UC South Coast Research and Extension Center, Irvine, CA.

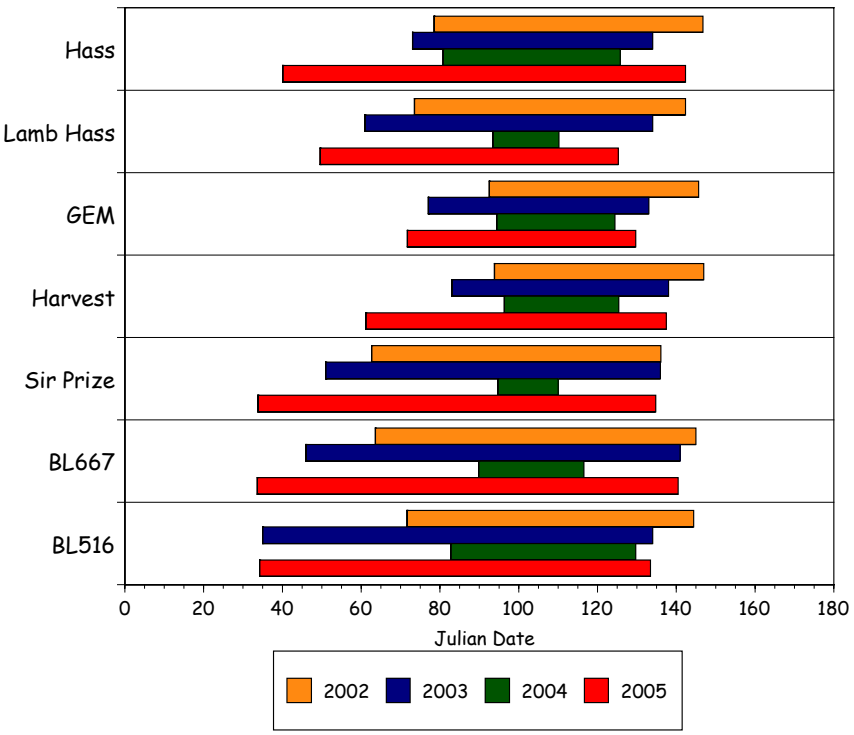

Figure 5. Distance from pollinizers influences the cumulative yield of 'Hass'. Data collected from 2002-2005 From the DeBusschere pollinizer trial near Oxnard.

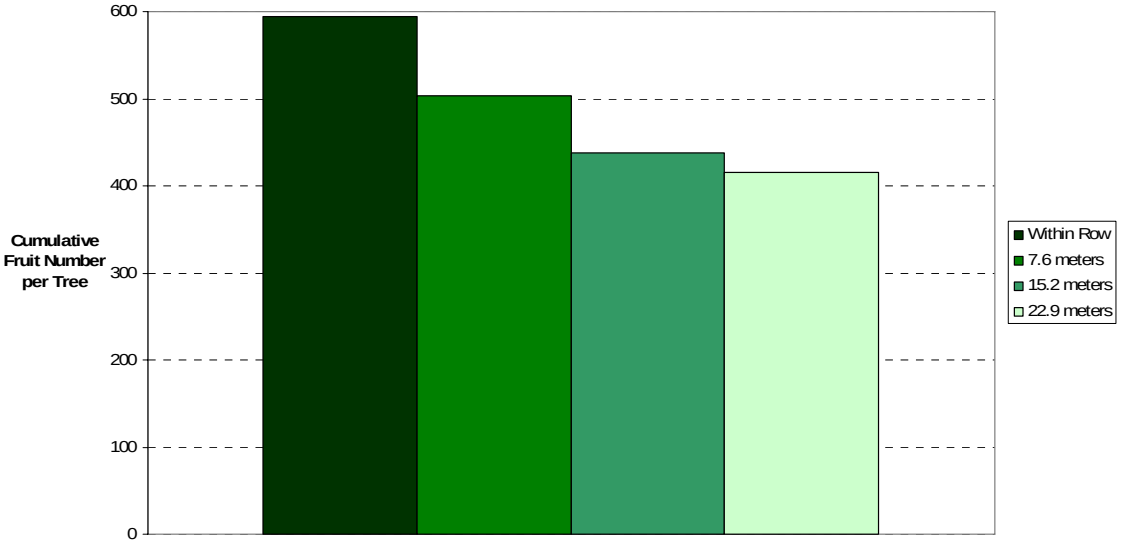

Figure 6. Cumulative 'Hass' fruit number (2002-2005) as a function of pollinizer variety. Data pooled across rows 0 – 2 (0 – 15.2 m). Data collected from the DeBusschere pollinizer trial near Oxnard, CA.