Breeding, Varieties & Genetics

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

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A formal avocado variety breeding program has existed at the University of California for several decades. The first controlled selections were made in 1937 by J. W. Lesley at UC Riverside, and in 1939 by W.E. Lammerts at UCLA (Lammerts, 1943). Dr. Art Schroeder, was also active in the selection of promising material in the 1930's and 1940's and participated in several plant exploration trips to Central America. In the 1950's the UC hired Dr. Royce Bringhurst (UCLA) to develop new avocado varieties. He was followed after a short tenure by Dr. Bob Bergh (UC, Riverside) in 1956 who worked on the development of new varieties until his retirement in the early 1990's. Gray Martin, carried on Dr. Bergh's work upon his retirement and was supervised by Dr. Guy Witney briefly in 1994 through 1996. Dr. Mary Lu Arpaia assumed full responsibility for the program in 1997. She has been assisted by Mr. David Stottlemyer (1996 – 2006) and by Mr. Eric Focht (2005 –present).

Dr. Bergh outlined the general breeding objectives for the California industry (Bergh, 1976; Table 1). With these objectives in mind, we have continued our program to search for improved varieties. The goal of the current program is to produce new avocado varieties, superior to 'Hass' in consistent production and fruit size. These new selections also must have Postharvest fruit quality equal or better than Hass: uniform fruit ripening, sensitivity to chilling injury and most importantly eating quality. Although it would be ideal to identify new varieties that have long harvest seasons, we will not necessarily eliminate promising material that have a more limited on-tree storage life or maturity season as compared to Hass.

This project aims to help maintain and enhance the California avocado industry by introducing consistently heavier producing, high-quality avocado varieties, better pollinizer varieties, and to test improved rootstock hybrids. The goals of this project will be achieved through continued evaluation of new material generated through traditional selection techniques, collaboration with Dr. Clegg and others as they develop refined techniques to increase the efficiency of selection and introduction of new material from other breeding and selection programs. Increasing the genetic diversity of varieties cultivated in California will decrease the risk of major pest and disease invasions on a susceptible monoculture. During the last year our activities have focused in the general areas described below.

1. Development of new varieties

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), J. Chaparro (Univ. of Florida, Gainesville) and A. W. Whiley (Australia). We have also continued to implement many of the suggestions offered by Drs. Chaparro and Lavi during their 2005 breeding program audit to streamline the breeding program and increase efficiencies.

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. Table 2 summarizes the number of seedlings that we have planted since 2000 at UC South Coast REC from "open-pollinated" sources.

Table 1. Avocado breeding objectives (Bergh, 1976).

Fruit quality	
Medium size	Thick ovate shape
Uniformity	Pulp
Skin	Proper softening
Medium thickness	Appetizing color
Readily peelable	Absence of fibers
Insect, disease resistance	Pleasing flavor
Free from blemishes	Long shelf life
Attractive color	Slow oxidation
Long tree storage	Chilling tolerance
Seed	High oil content
Small	High nutritional value
Tight in its cavity	
Shoot qualities	
Upright to slightly spreading habit	Tolerant of chlorosis
Easy to propagate	Tolerant of other stresses
Strong grower	Short fruit maturation period
Tolerant of pests and diseases	Precocious
Tolerant of wind	Regular bearing
Tolerant of cold	Wide adaptability
Tolerant of heat	Heavy bearer
Tolerant of salinity	

Table 2. Open pollinated seedlings from varying maternal sources planted at the UC South Coast Research and Extension Center from 2000 to Spring 2007.

Year Planted	5-552	5-Star	Bacon	BL1058	GEM	Green Gold	Gwen	Harvest	Lamb Hass	Marvel	Nobel	Murietta Green	SirPrize	XX3	Total Planted
2000*	32				39		14		5	90	37				217
2002					91				20	75	51				237
2003					41		55			50	25				171
2004	30				42		55			61	48				236
2005			3		99		23		60	60	73		36	11	365
2006	0	5	0	8	82	64	63	68	163	158	46	0	185	38	880
2007**					6	5	33		20						64
Totals*	62	5	3	8	400	69	243	68	268	494	280	0	221	49	2170

* 81% of these seedlings have now fruited and been evaluated. Tree removal of non-promising material will occur in Fall 2007 as well as trees which have not borne fruit.
** Total reported is for Spring planting only. Additional trees will be planted in October 2007.
*** Totals reflect actual trees planted through Spring 2007.

In the second approach we have taken the more traditional approach of Dr. Bergh by establishing isolation plots in various locations. Table 3 lists the location, year established and selections in each isolation block. The potential parents were selected under consultation with Dr. Bergh. A total of 928 seedlings have been thus far planted out from the isolation blocks (Table 4).

Table 3. 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.

Table 4. Seedlings from isolation blocks that are planted at the UC South Coast Research and Extension Center from 2003 to Spring 2007.

Year Planted	GEM x Marvel	GEM x Thille	Lamb Hass x Lamb Hass	Lamb Hass x Nobel	Lamb Hass x Reed	Marvel x GEM	Nobel x Lamb Hass	Reed x Lamb Hass	Reed x Stewart	Thille x GEM	Total planted
2003										15	15
2004	6										6
2005	113	179				12					304
2006	3	296	60		8	1			1	105	474
2007*	64	1		60	2			13	3	1	144
Totals**	186	476	60	60	10	13	0	13	4	106	928

** Total reported is for Spring planting only. Additional trees will be planted in October 2007.
*** Totals reflect actual trees planted through Spring 2007.

Each fall we do a fruit estimate on all seedling trees planted at UC South Coast REC. If multiple fruit are available, the fruit from the seedling will be sampled several times over the year. When only a few fruit are available then the trees are sampled only once during the season, generally in the Spring. When we sample fruit from the field we will collect data pertaining to fruit shape, weight and other general characteristics as well as dry weight (coring method) and ripe characteristics including flavor. Fruit that appear interesting are photographed and are entered into a database originally developed by Mr. Stottlemyer. Twelve seedlings have been selected for further evaluation from the 2000 and 2001 plantings. Two of these selections were selected for their sympodial growth habit; the others were selected mainly on the basis of flavor and/or maturity season. An additional seedling has been selected to be further propagated as a “seed parent”. This variety will be propagated in Field 4 at UC South Coast REC to increase the quality of the genetic pool; due to its elongated shape, however, it will not be considered for commercial development. This selection has been made in accordance with the suggestions of Dr. Jose Chaparro. This makes for a total of thirteen selections from fruit evaluated in 2005 - 2007. Trees of these selections are being propagated for further evaluation at UC South Coast REC.

The 2006 – 2007 seedling evaluation season was problematic from several perspectives. First, although very little tree damage occurred due to the January freeze, fruit drop on an already short crop reduced the number of fruit to be evaluated. Secondly, the controlled temperature chamber at UCR that we use to ripen fruit required an extensive overall. In the interim, fruit were ripened under ambient conditions with generally poor results. The chambers have now been reconditioned to provide both temperature and relative humidity control and are providing the conditions for proper fruit ripening.

We collected approximately 2400 seeds from the UCR and Nakamura Isolation plots during 2007. Additionally seeds were collected from targeted maternal parents (Table 2). These seeds are in the process of being germinated for field planting in 2008 and early 2009 and will be planted out most likely in Field 46 at UC South Coast REC. In order to do this we are removing several rows of older material. There are 4 rows of older germplasm material that are currently being moved and propagated elsewhere; this will be completed by the spring of 2008 and we will begin planting new selections in this

area at that point. In addition, we are assuring propagation of interesting material in many of the older rows of Field 46, removal of these rows will begin once we have assured there is nothing left of interest in these rows. We have continued to plant out new selections in Field 44 and have filled all available space in this field

We have begun converting Field 4 into a field that will produce seed from good parentage for the creation of new selections as suggested in the 2005 audit. Currently we have left roughly half of the older trees in combination with a mix of replanting and topworking of different germplasm into the field. We plan to remove all older trees in the next few years as we revamp this field to be the maternal seed source block for the scion breeding program. Topworking of promising or interesting maternal seed material was begun in February of 2007. Twenty-five new selection trees were planted in this field in April of 2007 for further (second stage) evaluation. In addition, 20 Duke7 trees are planned for planting in this field in the spring of 2008 for future topworking. Further 2nd stage new selections will be planted into this field at this time.

2. Overseas cooperation.

We have answered several questions regarding exchange of material with potential overseas cooperators and have done so on two occasions since November of 2006. We sent a shipment of 300 seeds to Israel to aid them in the restart of their breeding program, the 3 varieties that they received were 'Harvest', 'GEM' and 'BL516'. We also shipped budwood to the National Bureau of Plant Genetic Resources in New Delhi, India. The varieties received by this program were 'Gwen', 'Hass', 'Fuerte', 'Bacon', 'Zutano', 'Queen', 'Pinkerton' and 'Reed'

3. Introduction of new plant material.

In the Fall of 2004 we imported budwood from 2 new selections from Chile, 'Eugenin' and 'schiapicasse'. This material was removed from quarantine this spring and will be ready for planting and further propagation in the spring of 2008. In addition, 2 'Puebla' trees, received from Brokaw nurseries will be planted in field 4 in fall of 2007. We will compare these 'Puebla' trees to those propagated from budwood introduced from Chile several years ago. Propagation of self rooted dwarf *P. schiediana* is tentatively scheduled to be undertaken by Brokaw nurseries.

4. Sunblotch Testing.

We continue to test material within the program for Sunblotch with the assistance of Dr. Deb Mathews and Dr. Alan Dodds. Leaf samples were collected from fields 44 and 46 at SCREC. Of the 98 trees tested since 11/1/06, only one has tested positive. This was a tree from the Clegg lab project at UCR's Ag Ops field 9. The tree has been removed. In 2005 we began to institute a more aggressive policy to contain sunblotch; we now remove the negative or untested trees adjacent to a positive tree. Sunblotch testing has been completed on all trees in the heritage block (field 44) with one positive tree being removed in 2004; there have been no reoccurrences in this field since. Sunblotch testing has also been completed on all of the trees in Field 4 that are being used for seed production. New additions to the collection are tested prior to planting or grafting into the field.

5. Maintenance of the CAS Germplasm Plot and Persea species collection at UC South Coast REC

We have slowly revitalized the CAS germplasm plot and conducted sunblotch testing of interesting material. New selections have been added when possible. Budwood of non-protected material is distributed when requested. We also make selections in our heritage collection available to nurseries. Since November 2006, we have supplied over 1480 budsticks to various nurseries for the following varieties: 'Edranol', 'Stewart', 'Fuerte', 'Lamb Hass', 'XX3' and 'Nimlioh'.

We continue to maintain a small species collection at UC South Coast REC that was planted by Dr. Rainer Scora in the late 1980's and early 90's.

6. Rootstock and pollinizer evaluation

We have conducted a number of rootstock trials at UC South Coast REC. These trials are planted out under non-root rot conditions in order to evaluate the productivity of 'Hass' as influenced by rootstock. In Spring 2007, we published a paper summarizing the results of this first rootstock trial (Mickelbart et al, 2007). Reprints are available upon request or for downloading at www.avocadosource.com.

In 1999 we established a new rootstock trial at UC South Coast REC. This trial includes both 'Hass' and 'Lamb Hass' on several interesting rootstocks from the Menge program (Day*, Duke 7*, Dusa, Evstro*, G755A, Parida, Spencer, Thomas*, Toro Canyon*, and Zentmyer; * = 'Lamb Hass'). We also have 1 row of 'Carmen Mendez' on Toro Canyon for evaluation of that variety. Due to the freeze California experienced early in 2007, this trial was harvested early. Both 'Hass' and 'Lamb Hass' were harvested and although the 'Lamb Hass' was not mature, it was apparent that a great deal of the fruit would be lost due to freeze damage to the fruit stems. In addition, the frost-damaged parts of the trees were trimmed and removed by field staff in early February, a week after the harvest was completed. The data has been summarized and is presented in Figures 1 – 3. Figure 1 reports the yield for the 'Hass' portion of the trial. The overall yield for 2007 is reduced for this year both in terms of fruit numbers (not shown) and fruit weight. There were few statistical differences between the rootstocks with the exception of Day and G755A which had significantly more fruit. In terms of cumulative yield, no statistical differences were detected in 'Hass' yield due to rootstock. The 'Lamb Hass' dataset is similar (Figure 2). As of the 2007 harvest, there are no statistical differences in yield due to rootstock both in terms of the 2007 yield data or cumulative yield (weight or fruit count). When comparing yield of 'Hass' and 'Lamb Hass' on the same rootstocks (Figure 3) there were no significant differences in yield as well as fruit count.

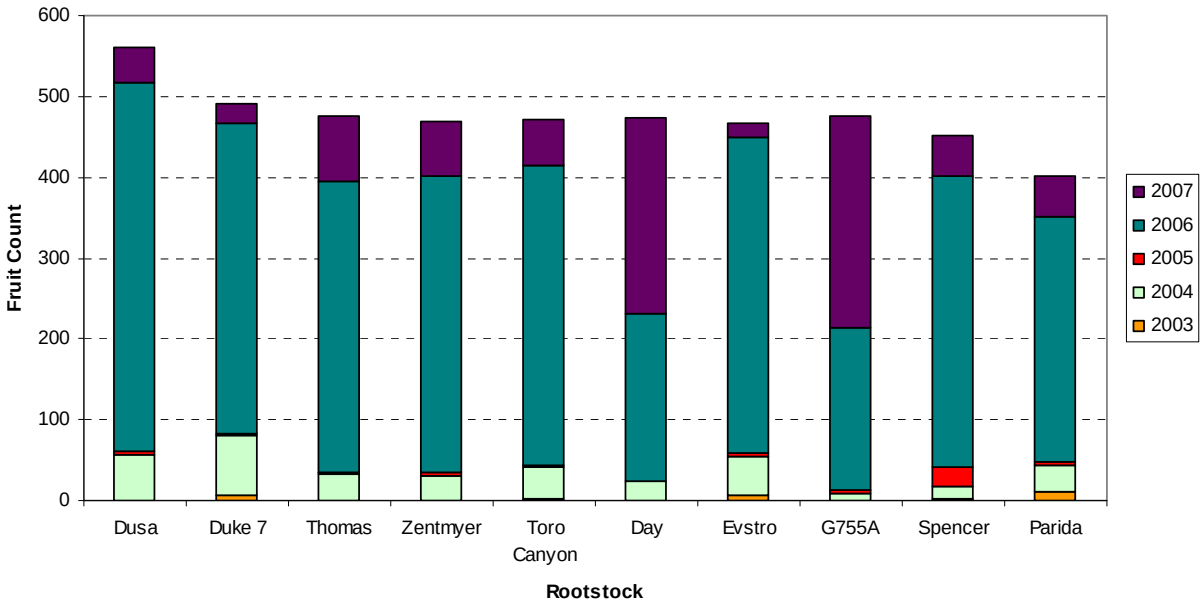

Figure 1. Cumulative yield by year for 'Hass' on several rootstocks. Plot at the UC South Coast Research and Extension Center in Irvine, CA. Trees planted in 1999.

DeBusschere Pollinizer Plot. The 'Hass' trees in this trial in Oxnard were planted in 1998 and the pollinizer trees in July 1999. We harvested the DeBusschere Pollinizer plot in March 2007. We collected one week prior to harvest, 8 'Hass' fruit (6.98 oz average size) from each pollinizer row (6 replications). Dry weight was determined for each fruit (a special thanks to Donella Boreham and her staff from the Avocado Inspection Service). We also measured the length and width of each fruit and seed as well as the fruit and seed weight and rated the color of the seed coat. Table 5 presents the means of the fruit data we have collected over the last several years. Note for all parameters, that

significant differences can be detected in the 'Hass' fruit relative to pollen source. The thing that is lacking in this study is a paternity analysis to see the percentage outcrossing that may occur.

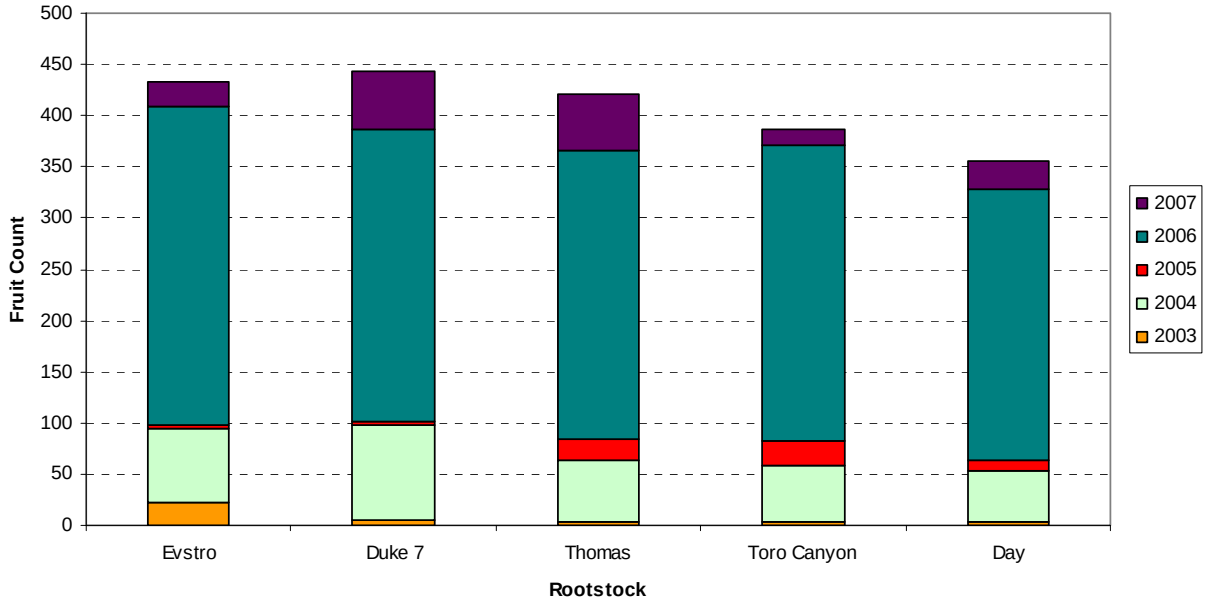

Figure 2. Cumulative yield by year for 'Lamb Hass' on several rootstocks. Plot at the UC South Coast Research and Extension Center in Irvine, CA. Trees planted in 1999.

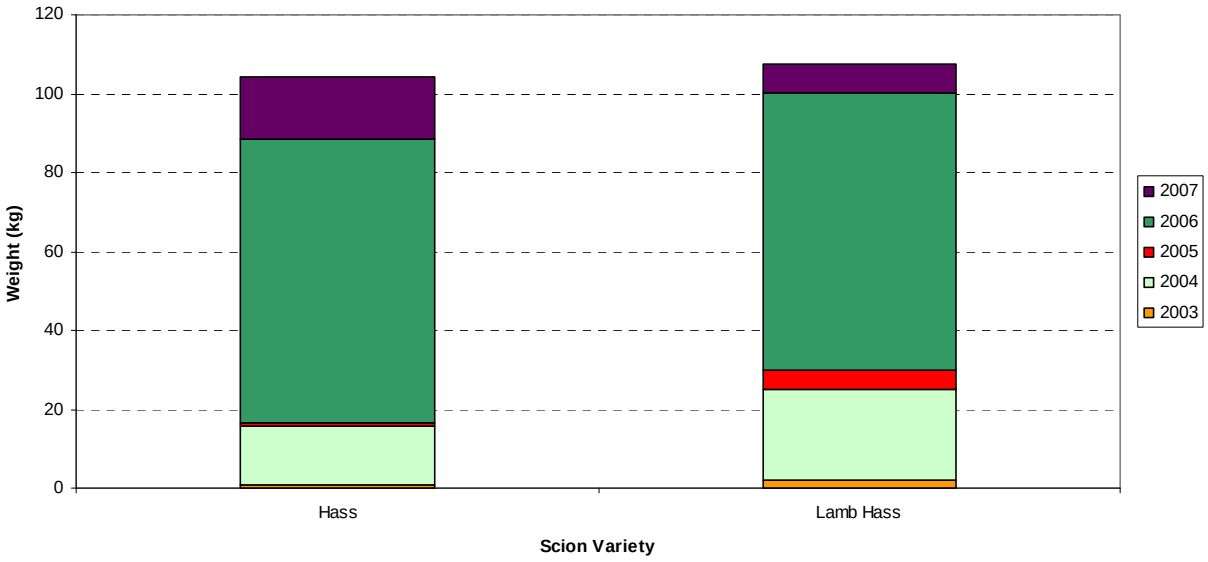

Figure 3. Cumulative yield by year for 'Hass' and 'Lamb Hass'. Comparison based on cultivars on the same rootstocks. Plot at the UC South Coast Research and Extension Center in Irvine, CA. Trees planted in 1999.

The overall yield this year was slightly lower than 2006 and ranged between 80 to 247 fruit per tree regardless of distance from the pollinizer source. Figures 4 and 5 utilize data from 2002 through 2007. We have dropped the yield data from 2001 since only 3 of the 6 field replications were harvested that

year. Figure 3 shows the average yield (fruit number per tree) for 2007 as a function of pollinizer source and distance from the pollinizer. For this year, yields near 'Bacon' were the highest, and yields near 'Fuerte' which has been high for the last several years were reduced. However when cumulative yield (fruit count) is considered, the highest yields continue to be associated with 'Fuerte' as the pollinizer. Figure 4 presents the cumulative yield data as expressed by fruit number for 2002-2007. Clearly, proximity to a pollinizer has an impact on cumulative yield as reported in Table 6. This preliminary analysis included factoring in the middle row (3 rows from the Pollinizer) and distance from windbreaks. Based on preliminary detailed data analysis of the entire data set, we plan to collect one additional year of yield data in Spring 2008.

Table 5. The influence of Pollinizer variety on 'Hass' fruit characteristics. Mean separation by LSD, P<0.05 (n.s. = not significant).

Closest Pollinizer	Average. Dry Weight (2004 – 2007) (%)	Average Seed Length/Width Ratio (2004 – 2007)	Average Fruit Length/Width Ratio (2004 – 2007)	Average Percent Seed Size (2005 – 2007) (%)	Average Seed Coat Color (2006 – 2007) (1 – 5)
Bacon	25.49 ab	1.14 bc	1.43 ab	12.39 c	3.18 ab
Ettinger	24.67 bc	1.13 cd	1.42 ab	12.51 c	2.78 bc
Fuerte	24.96 bc	1.17 a	1.45 a	12.28 c	2.53 c
Harvest	25.46 ab	1.16 ab	1.45 a	12.77 bc	3.44 a
Marvel	24.22 c	1.14 bc	1.43 ab	14.50 a	3.11 abc
Nobel	26.32 a	1.15 abc	1.44 ab	12.56 bc	3.31 ab
SirPrize	24.91 bc	1.13 cd	1.42 ab	13.11 abc	2.79 bc
Zutano	24.58 bc	1.11 d	1.41 b	14.08 ab	2.73 bc

Table 6. The influence of distance from a Pollinizer on yield (fruit count). Tree rows are spaced at 27 ft. Mean separation by LSD, P<0.05.

Rows from PZ	Fruit count													
	2002		2003		2004		2005		2006		2007		Cumulative	
0	178.8	a	29.6	a	341.9	a	44.8	a	196.8	a	163.6	b	955.6	a
1	179.2	a	21.8	b	248.4	b	52.1	ab	140.5	b	198.0	a	840.0	b
2	152.6	b	15.9	b	212.9	c	55.4	a	129.5	b	156.3	b	722.5	c
3	168.9	ab	20.6	b	224.5	bc	49.1	ab	134.8	b	177.4	ab	775.3	c

7. Outreach Activities

These can be summarized into 3 general areas:

1. **Web Site.** The web site continues to be updated and changed on a periodic basis. We plan a major overhaul and update of the software and operating system for the website and server in the upcoming fiscal year
2. **Answered Email.** We have received and answered numerous email requests for information on avocados since November 1, 2006. These range from specific questions regarding avocado germplasm to questions from avocado enthusiasts worldwide.
3. **Visit to Chile, November 2007.** In November of 2007, M. L. Arpaia will visit Chile for the World Avocado Congress. The purpose of this visit was to exchange information pertaining to both rootstock and scion development. In addition, E. Focht will be traveling to Chile for the 'avocado

brainstorming' meeting after the Congress. From this programs perspective, the trip will create and reinforce long standing relationships of this program with that of others of its kind throughout the world.

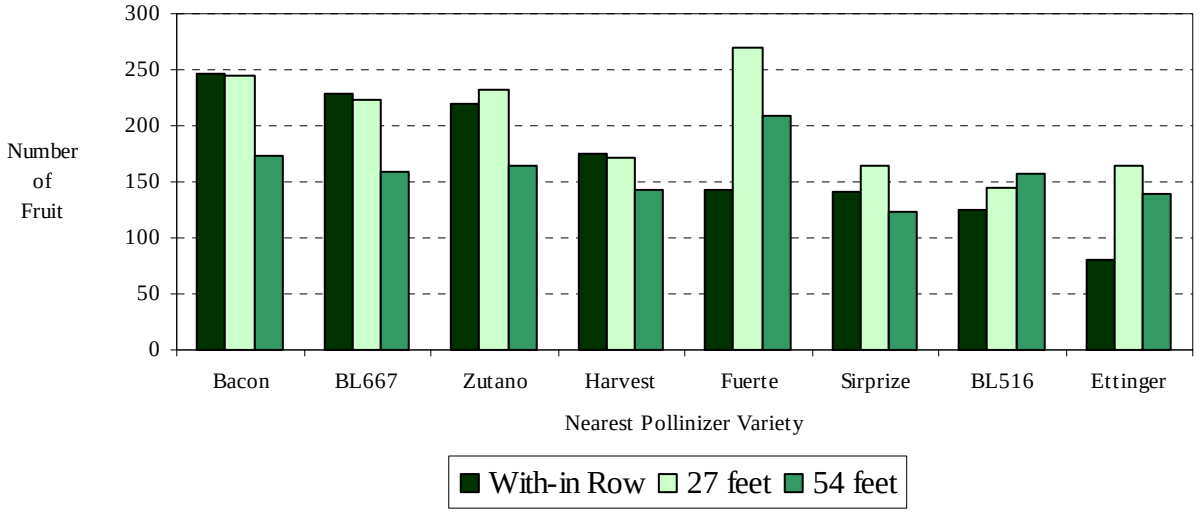

Figure 4. The average number of 'Hass' fruit per tree as a function of distance from a pollinizer variety. Fruit harvested in March 2007 from the DeBusschere pollinizer plot near Oxnard, CA.

4. **Other Outreach Activities.** We have given several presentations of data collected from this trial, as requested. This has included several field tours as well as oral presentations to grower groups and visitors to the field station.

Planned Activities for Remainder of Fiscal Year:

1. In additions to the planting of new seedling selections at SCREC in April 2007, we plan to plant approximately 250 additional seedlings in October 2007.
2. Further propagation of varieties of interest from our new selections' seedlings. Promising selections will be topworked or grafted onto Duke 7 clonal rootstock.
3. Further collection of seed to provide a total of more than 2000 seeds in 2008 for the new selections.

Selected References *(All references available at www.avocadosource.com)*

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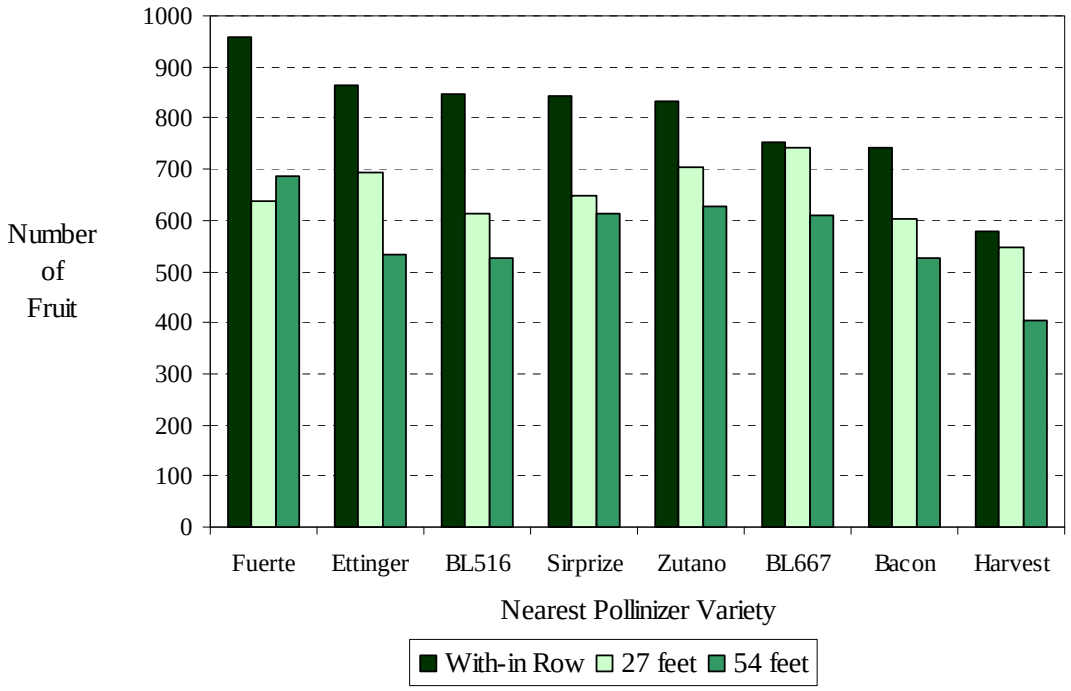

Figure 5. The average cumulative number of 'Hass' fruit per tree as a function of distance from a pollinizer variety from 2002 - 2007. Fruit harvested from the DeBusschere pollinizer plot near Oxnard, CA.