## 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 from 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. We believe that it is imperative that the California industry have an array of varieties to grow throughout the commercial season. Past history in other agronomic crops has clearly highlighted the dangers of single variety industries in terms of pest and disease outbreaks.

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, Dr. Raymond Schnell 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 following 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. 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 1,474 seedlings have been thus far planted out from the isolation blocks (Table 4).

**Table 1.** Avocado breeding objectives (Based on Bergh, 1976).

| **Fruit quality** | |
|---|---|
| **Size and shape** | **Pulp characteristics** |
| Medium size | Proper softening |
| Thick ovate shape | Appetizing color |
| Fruit uniform in size and shape | Absence of fibers |
| **Peel characteristics** | Pleasing flavor |
| Medium thickness | Long shelf life |
| Readily peelable | Slow oxidation |
| Insect and disease resistant | Chilling tolerance |
| Blemish free | High oil content |
| Attractive color | High nutritional value |
| **Seed characteristics** | |
| Small | |
| Tight in its cavity | |
| **Tree characteristics** | |
| 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 | Long tree storage |

**Table 2.** Open pollinated seedlings from varying maternal sources planted at the UC South Coast Research and Extension Center from 2000 to Fall 2008.

| Year Planted | 5-552 | 5-Star | Bacon | BL1058 | GEM | Green Gold | Gwen | Harvest | Lamb Hass | Marvel | Nobel | 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 | | 5 | | 8 | 82 | 64 | 63 | 68 | 163 | 158 | 46 | 185 | 38 | 880 |
| 2007 | | | | | 6 | 5 | 33 | | 20 | | | | | 64 |
| 2008 | | | | | 63 | 23 | 6 | | 8 | | | 44 | | |
| **Totals*** | 62 | 5 | 3 | 8 | 463 | 92 | 249 | 68 | 276 | 494 | 280 | 265 | 49 | 2314 |

* Totals reflect actual trees planted through Fall 2008.

**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 2008.

| Year Planted | GEM x Marvel | GEM x Thille | GEM x GEM | Lamb Hass x GEM | 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 |
| 2008 | 258 | 42 | 12 | 1 | 1 | 50 | 4 | 49 | 10 | 16 | 2 | 86 | 531 |
| **Totals*** | 444 | 518 | 12 | 1 | 61 | 110 | 14 | 62 | 10 | 29 | 6 | 207 | 1474 |

* Totals reflect actual trees planted through Fall 2008.

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. Additionally, in the 2008 evaluation season, an additional 3 selections were made based on fruit quality. This makes for a total of sixteen selections from fruit evaluated in 2005 - 2008. Trees of these selections are being propagated for further evaluation at UC South Coast REC. (Additional information on these selections are available upon request and were shared with the PRC Genetics Subcommittee when they visited the South Coast REC in July 2008.

We collected approximately 1136 seeds from the UCR and Nakamura Isolation plots during 2008. Additionally 615 seeds were collected from targeted maternal parents (Table 2). These seeds are in the process of being germinated for field planting in 2009 and early 2010 and will be planted out most likely in Field 46 at UC South Coast REC. In order to find room for our continued plantings, we have removed several rows of older material that has already been evaluated and re-propagated when appropriate.

In 2009 we plan to begin the removal of rows 71-74 in field 46 as these have been in the ground for an average of 6 years (33.47% of trees in these rows have been evaluated). Next year should be the last year for evaluation of trees in rows 75-81 in field 46 (13.80% of trees in these rows have been

evaluated). Conditions in the extreme north of this field should be contrasted to more favorable conditions in rows 29-39 of field 44 where after only one year of fruit data collected (2008) we have already evaluated 11.86% of the trees. In the future we do not plan to use these poor and unproductive rows of field 46. Instead, we have begun coordinating with the REC management to begin using a more productive section in the southernmost portion of field 45. This section of the field station should be ready for planting in fall of 2009. We have filled all available space in Field 44, as the soil conditions here are favorable; we expect that many of these trees to produce fruit for the 2009 evaluation period.

Field plantings in the fall of 2007 were hampered by a combination of Santa Ana winds and a miscommunication among field staff. Prior to the October planting date, seedling trees in their 1 gallon sleeves were over fertilized and suffered severe saltburn. Although only the healthiest of these damaged trees were planted out in the field, severe dry, windy conditions the following week resulted in 70% mortality in this planting. Those severely salt burned seedlings which were not chosen for planting out suffered slightly less than 50% mortality after field station staff flushed the sleeves to leach out the fertilizer. South Coast REC staff has since agreed to leave fertilizing and application of supplements to the research staff; the 2008 planting season went off without any similar incident.

We have begun converting Field 4 into our maternal seed block 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 began 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, 40 Duke7 trees were planted in this field in 2008 for future topworking; we expect to begin topworking the oldest of these Duke7 in the spring of 2009. Further 2$^{nd}$ stage new selections were planted into this field in 2008, bringing our total of 2$^{nd}$ tier trees to 60.

***2. Overseas cooperation.***

We have answered several questions regarding exchange of material with potential overseas cooperators and are coordinating these activities with the Office of Technology Commercialization at UC Riverside.

***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 was planted in the field in 2008. In addition, 2 ‘Puebla’ trees, received from Brokaw nurseries were 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. In addition, we have begun collaboration with Dr. Raymond Schnell and are providing him with leaf samples for genetic analysis; his lab has identified many more microsatellite sites for avocado and it is hoped that he will be able to provide more insight into several ‘Hass’-like varieties as well as the parentage of some of our 2$^{nd}$ tier selections. This will not only clear up some questions in regards to some of the ‘Hass’-like cultivars, but may also help to streamline our breeding process if we are able to positively identify the source of paternity.

***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 4, 44, and 46 at SCREC. . 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. In the past year, we have detected 5 positive trees; these were mostly in an area of field 46 that had previously produced positive ASBVD results. In particular, we have found a several

positive trees in rows 1 through 6 and as there is not currently any material of interest in this section of the field, we have gone ahead with the removal of this entire section.

### *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 continue to make selections in our heritage collection available to nurseries upon request. 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 1990'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 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.

The yield data has been summarized and is presented in Figures 1 – 3. Figure 1 reports the yield for the 'Hass' portion of the trial. The ranking of the rootstocks changed quite dramatically this year primarily due to the heavy crop of 'Hass' on the Evstro (Latas) rootstock. In terms of cumulative yield, the top 4 highest yielding rootstocks (Evstro, Dusa, Duke 7 and Zentmyer) are not statistically different from each other. There are small but significant differences in average 'Hass' fruit size due to rootstock. The smallest fruit have been from 'Hass' on the Spencer, Parida and G755A rootstocks. The largest fruit have come from the Dusa, Duke 7 and Zentmyer rootstocks.

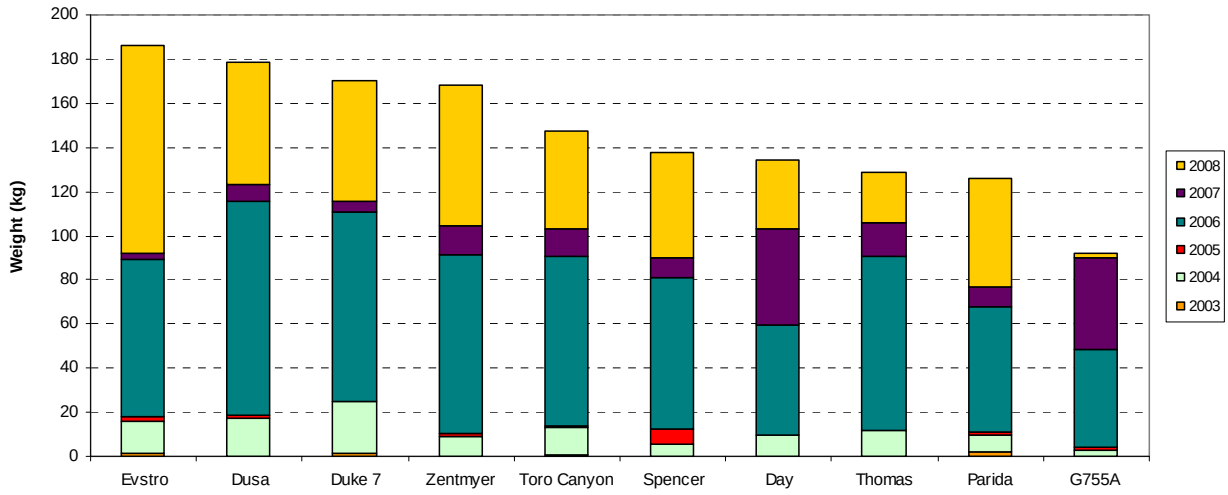


**Figure 1.** Cumulative yield by year for 'Hass' on several rootstocks. Plot at the UC South Coast Research and Extension Center in Irvine, CA. Trees planted in 1999.

The 'Lamb Hass' dataset is similar (Figure 2) with the Evstro rootstock producing the highest yield. Interestingly, the Thomas is the second most productive rootstocks for the Lamb Hass and is not statistically different from the Evstro rootstock. It will be interesting to see if this difference with 'Hass' persists. Our results from a previous clonal rootstock trial in combination with 'Hass' were similar to that reported in Figure 1. As of the 2008 harvest, there are no statistical differences in average fruit size

due to. When comparing yield of 'Hass' and 'Lamb Hass' on the same rootstocks (Figure 3) the Evstro once again has this year had significantly higher annual and cumulative yield. At this time there is no significant difference between 'Hass' and 'Lamb Hass' with respect to cumulative yield, although we have harvested significantly greater numbers of fruit from the 'Hass' due to the variety's smaller fruit size. There was no significant rootstock x scion interactions detected.

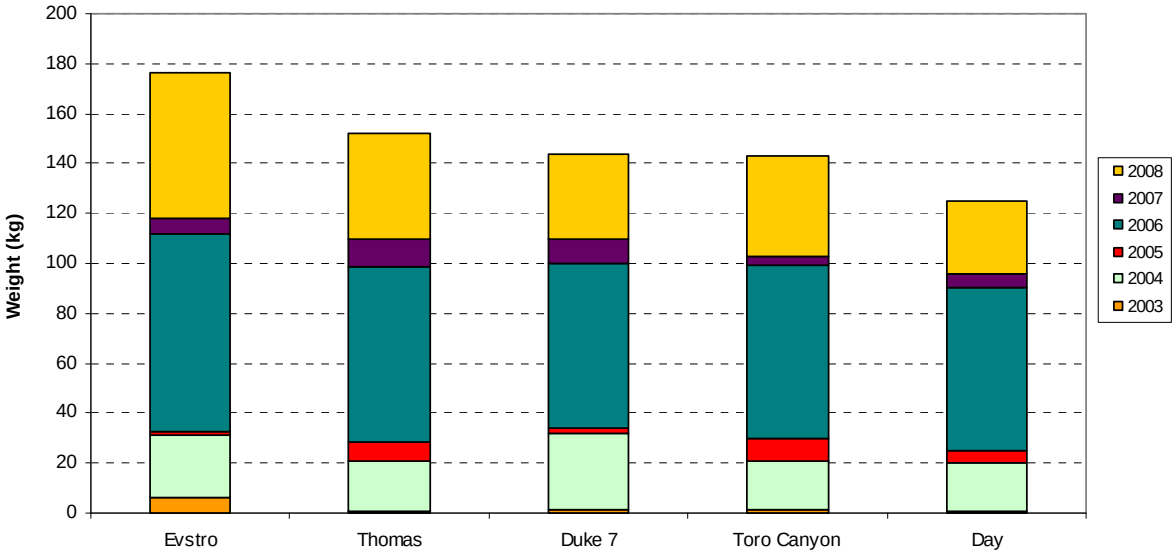


**Figure 2.** Cumulative yield by year for 'Lamb Hass' on several rootstocks. Plot at the UC South Coast Research and Extension Center in Irvine, CA. Trees planted in 1999.

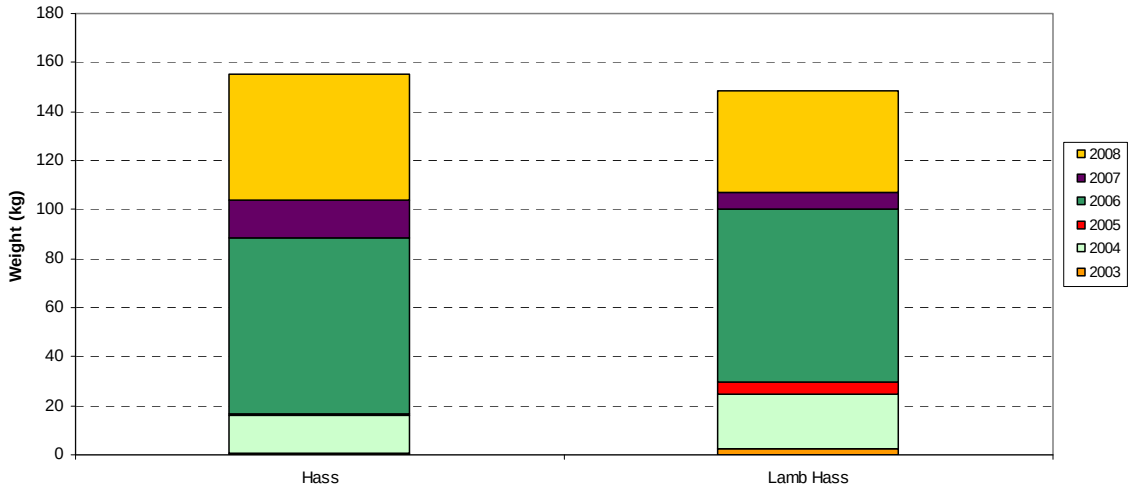


**Figure 3.** Cumulative yield by year for 'Hass' and 'Lamb Hass'. Comparison based on cultivars on the same rootstocks. Plot at the UC South Coast Research and Extension Center in Irvine, CA. Trees planted in 1999.

**DeBusschere Pollinizer Plot.** The 'Hass' trees in this trial in Oxnard were planted in 1998 and the pollinizer trees in July 1999. The final year of yield data (year 6) was collected in March 2008. 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. We are currently in the process of summarizing the 6 years of yield data from this trial.

**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 have contracted with David Stottlemyer to update the website in the coming months and to add new information.
2. **Answered Email.** We have received and answered numerous email requests for information on avocados since November 1, 2007. These range from specific questions regarding avocado germplasm to questions from avocado enthusiasts worldwide.
3. **Site visits to UC South Coast REC.** We have hosted several visitors (domestic and international) who have expressed interest in the avocado scion breeding program. We have also participated in industry related tours whenever requested.
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. Further propagation of varieties of interest from our new selections' seedlings. Promising selections will be topworked or grafted onto Duke 7 clonal rootstock.
2. 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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