Why have an Improvement Program

Producing the Crop - Enhancing Productivity
- High production of optimally sized fruit
- Tolerance to disease, pests
- Tolerance to environmental stress
- Tree “manageability”
- On-tree storage and minimize alternate bearing

Marketing the Crop - Maximizing Fruit Quality
- Minimizing physiological disorders
- Uniformity of ripening
- Tolerance to low storage temperatures
- Tolerance to handling “mis-management”
- Decreased postharvest fruit decay
**Requirements/Risks of a plant improvement program**

- Long-term venture (10 - 20 years)
- Requires coordinated effort: academia, growers, packers, consumers
- Wide-scale adoption unknown: will there be a return on the investment?
- Most current cultivars and rootstocks are local selections - can improvements be found?

**Challenges Specific to Avocado Plant Improvement**

- Avocado is "relatively primitive" - commercial production <100 years
- Understanding limited on avocado genetics
- May be many years to come into production
- Highly heterozygous - seedling populations extremely varied
The goals of an avocado improvement program can be achieved through **varietal and rootstock** manipulation using either traditional breeding methods or as technology improves, molecular techniques.

Additionally, an important component for the future is **germplasm conservation**. Characterization and preservation of wild *Persea* and related genera is essential in order to preserve desirable traits useful for future breeding efforts.

**University of California**  
Avocado Improvement Program

**Rootstock Selection Program**  
Disease tolerance - J. Menge, G. Zentmyer  
Salinity tolerance - D. Crowley, M. L. Arpaia  
Field Productivity - M. L. Arpaia, G. Bender, B. Faber

**Varietal Improvement** - M. L. Arpaia

**Genetic Characterization** - M. Clegg, T. Chao

**Germplasm Conservation** - R. Scora, J. Menge, M. L. Arpaia
Contributions of UC Avocado Program

Rootstocks
Identification of PRR tolerant material
Rootstock productivity and salinity tolerance
Dwarfing

Cultivars
New varieties for CA growers
Breeding stock shared with international community and has been the foundation of other int'l breeding programs

Avocado Breeding Program

Components

• Testing current selections
• Developing new selections
Varietal Selection UC, Riverside

B. O. Bergh: 1964 - 1994
M. L. Arpaia: 1996 - present

Technical Support:
Bob Whitsell 1964 - 1989
Gray Martin 1984 – 1997
David Stottlemyer 1997 - present

Varietal breeding in California

Current major cultivars are "local" or introduced selections

Released Cultivars to CA industry
Dr. B. O. Bergh and Mr. R. Whitsell
Gwen, Whitsell and Esther - released in 1984
Dr. B. O. Bergh and Mr. G. E. Martin
Lamb Hass and Sir Prize - released in 1996

Released 2003
Dr. Mary Lu Arpaia and Mr. David Stottlemyer
3-29-5 (GEM) and N4 (-) 5 (Harvest)
Components of evaluation

- **Yield**
- **Fruit characteristics - size, seed size**
- **Maturity and postharvest quality**
- **Tree vigor - growth habit**
- **Flowering, stress tolerance**
Leaf Shape - The unreleased varieties are all ‘Gwen’ offspring. Although the leaves tend to be similar, there are subtle differences between the varieties.
Yield
UC South Coast REC, Topworked Trees

Alternate Bearing Tendency
UC South Coast REC, Topworked Trees
Yield
DeBusschere Variety, Clonal Duke 7 RS

Flowering at UC South Coast REC in Irvine, CA. for 2002 - 2004

Flowering varies from year to year
Fruit Maturity
3-29-5 (GEM)

Similar pattern of dry matter accumulation to Hass

Comparison of dry matter changes over season

Fruit Maturity
N4 (-) 5 (Harvest)

Slower pattern of dry matter accumulation to Hass

Comparison of dry matter changes over season
**Differences between Hass and Lamb Hass**

- **Hass maturity season** - mid to late summer
- **Fruit shape** - more “square”
- **Lamb Hass has more upright growth habit**
- **Flexible wood** - fruit borne interior of tree; tends to set fruit in clusters
- **Lamb Hass is more “tolerant” to Persea mite and other pests (?)**
- **Photosynthetic rate** approximately 30% higher than Hass and higher chlorophyll content

**Fruit Maturity - Lamb Hass**

Delayed dry matter accumulation compared to Hass

Pattern of accumulation similar over seasons
**Avocado Breeding Program**

**Developing new selections**

1. **In consultation with U. Lavi (Israel)**
   
   Seed collection:
   - BL667, BL516, GEM,
   - Gwen, Lamb Hass, 5-552

2. **In consultation with B. Bergh**

   Isolation Blocks:
   - BL516 x GEM  Gwen self
   - Thille x GEM  Lamb x GEM
   - Sir Prize x Gwen  BL667 x Lamb
Indexing for disease is a critical component

Critical to know:
- Relative disease tolerance
- All introduced material should be tested

Clonal Rootstocks
The California Experience
Rootstocks can influence many scion characteristics

- Yield
- Tree size/vigor
- Yield efficiency
- Leaf nutrient status
- Tolerance to environmental stresses

Use of clonal rootstocks relatively new

- Potential for future improvements high
- Significant differences due exist
- More uniform tree performance possible
Table 6: Yield efficiency (kg fruit m⁻³) of ‘Hass’ avocado trees growing on ten clonal rootstocks at the University of California South Coast Research and Education Center (latitude, 33°44'N; longitude, 117°49'W) (n=20).

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>1991/92</th>
<th>1993/94</th>
<th>1995/96</th>
<th>mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>G755A</td>
<td>0.48c</td>
<td>0.87c</td>
<td>0.238c</td>
<td>0.57c</td>
</tr>
<tr>
<td>G755B</td>
<td>0.48cd</td>
<td>0.83cd</td>
<td>0.182c</td>
<td>0.50cd</td>
</tr>
<tr>
<td>G755C</td>
<td>0.42d</td>
<td>0.69d</td>
<td>0.236c</td>
<td>0.45d</td>
</tr>
<tr>
<td>Topa Topa</td>
<td>0.81b</td>
<td>1.06b</td>
<td>0.835a</td>
<td>0.92b</td>
</tr>
<tr>
<td>Duke 7</td>
<td>0.97a</td>
<td>1.23a</td>
<td>0.935a</td>
<td>1.05a</td>
</tr>
<tr>
<td>Borden</td>
<td>0.96ab</td>
<td>1.17ab</td>
<td>0.935a</td>
<td>1.02b</td>
</tr>
<tr>
<td>D9</td>
<td>0.95ab</td>
<td>1.13ab</td>
<td>0.94ab</td>
<td>0.99ab</td>
</tr>
<tr>
<td>Toro Canyon</td>
<td>0.90ab</td>
<td>1.13ab</td>
<td>0.94ab</td>
<td>0.99ab</td>
</tr>
<tr>
<td>G1033</td>
<td>0.58</td>
<td>0.94</td>
<td>0.69</td>
<td>0.74</td>
</tr>
</tbody>
</table>

Mean separation tests within columns non-significant (n.s.), or significant at the P=0.05 (+) or 0.001 (***-) level based on Fisher’s Protected LSD test.

Significant differences in yield efficiency

Yield efficiency declines due to increases in tree size and loss of productive canopy surface

Mean separation tests within columns non-significant (n.s.), or significant at the P=0.05 (+) or 0.001 (***-) level based on Fisher’s Protected LSD test.
Alternate Bearing can be influenced by clonal rootstock

Table 2. Alternate bearing index of ‘Hass’ avocado trees growing on ten clonal rootstocks at the University of California South Coast Research and Education Center (latitude, 33°44’N; longitude, 117°49’W). See Materials & Methods section for calculation.

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>Alternate bearing index</th>
</tr>
</thead>
<tbody>
<tr>
<td>G755A</td>
<td>1.49c</td>
</tr>
<tr>
<td>G755B</td>
<td>1.25d</td>
</tr>
<tr>
<td>G755C</td>
<td>1.21d</td>
</tr>
<tr>
<td>Topa Topa</td>
<td>1.91a</td>
</tr>
<tr>
<td>Duke 7</td>
<td>1.61bc</td>
</tr>
<tr>
<td>Borchard</td>
<td>1.70b</td>
</tr>
<tr>
<td>D9</td>
<td>1.56bc</td>
</tr>
<tr>
<td>Toro Canyon</td>
<td>1.92a</td>
</tr>
<tr>
<td>Thomas</td>
<td>1.83</td>
</tr>
<tr>
<td>GI033</td>
<td>1.63</td>
</tr>
<tr>
<td>n.s.</td>
<td></td>
</tr>
</tbody>
</table>

Mean separation tests within columns non-significant (n.s.) or significant at the P=0.001 (*** level based on Fisher’s Protected LSD test.
Rootstock can influence leaf nutrient status

Rootstocks affect 'Hass' avocado fruit rots - believed related to calcium uptake
4 wks @ 5C
Marques, Hofman et al 2001

Flesh volume (%)
**'Hass' Avocado Phenology Model**

"On" year = heavy crop load  
"Off" year = light crop load

![Graph showing relative growth rate over Julian date with shoot, root, and bloom phases marked.]

**Are there rootstocks affects?**

**Root growth rate - No consistent differences**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>'Thomas'</td>
<td>0.75ab</td>
<td>0.72</td>
<td>0.67a</td>
<td>0.52a</td>
<td>0.38a</td>
</tr>
<tr>
<td>'Topa Topa'</td>
<td>0.84a</td>
<td>0.97</td>
<td>0.75a</td>
<td>0.32bc</td>
<td>0.25b</td>
</tr>
<tr>
<td>'Duke 7'</td>
<td>0.60c</td>
<td>0.69</td>
<td>0.47b</td>
<td>0.18c</td>
<td>0.23b</td>
</tr>
<tr>
<td>'D9'</td>
<td>0.67bc</td>
<td>0.72</td>
<td>0.75a</td>
<td>0.38ab</td>
<td>0.24b</td>
</tr>
</tbody>
</table>

Sign. of F*:  * n.s.  **  *  *

*Means within a column with no letter(s) in common are significantly different (Fisher's Protected Least Significant Difference test at P≤0.05).

*n.s., *, **, *** are non-significant, or significant at P≤0.05, P≤0.01, or P≤0.001, respectively.
Rootstock had no effect of shoot growth rate

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>spring</td>
<td>summer</td>
<td>spring</td>
<td>summer</td>
<td>spring</td>
</tr>
<tr>
<td>'Thomas'</td>
<td>0.68</td>
<td>0.37</td>
<td>3.57</td>
<td>4.57</td>
<td>1.60</td>
</tr>
<tr>
<td>'Topa Topa'</td>
<td>0.65</td>
<td>0.26</td>
<td>5.71</td>
<td>5.81</td>
<td>1.80</td>
</tr>
<tr>
<td>'Duke 7'</td>
<td>0.61</td>
<td>0.27</td>
<td>5.34</td>
<td>6.49</td>
<td>2.00</td>
</tr>
<tr>
<td>'D9'</td>
<td>0.63</td>
<td>0.16</td>
<td>5.05</td>
<td>6.59</td>
<td>1.82</td>
</tr>
<tr>
<td>Sig. of F</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Avg.</td>
<td>0.64</td>
<td>0.27</td>
<td>4.92</td>
<td>5.86</td>
<td>1.80</td>
</tr>
</tbody>
</table>

*Spring = average of spring (first) flush; Summer = average of summer (second) flush.

Environmental Stress - Phytophthora root rot

Disease resistance/tolerance possible
New selections

Young avocado with root rot resistant rootstock growing among older avocados dying from avocado root rot
Breeding program

Breeding blocks of resistant varieties planted together to enhance natural crossing.

Screening and greenhouse evaluation of rootstocks

Fruit from breeding blocks is germinated in the greenhouse and inoculated with Phytophthora cinnamomi.

Selected resistant seedlings are reinoculated each time they are repotted.
Resistant varieties are grafted to stumps in the field to get abundant budwood for experiments.

Production of clonal rootstocks for experiments

Field Evaluation

Resistant rootstocks grown in Phytophthora-infested soil
Environmental Stress - Salinity

San Diego County
Stehly Trial

Latas VC801 VC218 VC256
Duke 7 Toro Canyon Thomas PP4 Zutano

December 2001
What we know - Much yet to be learned

Differences between avocado races needs to be better understood

Clonals can improve overall tree performance and potentially postharvest quality

As with other tree crops; with time we will find that varying environmental conditions will require different rootstocks

- Salinity, Disease, Cold, Soil
Greater cultural, harvesting and water costs coupled with increasing market competition

Approaches for the future

Enhancing Productivity

- Understanding avocado tree physiology and stress responses
- Light manipulation
- High density plantings
- Rootstocks for disease, salinity tolerance, dwarfing
- Varieties with productivity, pest tolerance, suitable for close spacings
- Pollinizers and Pollinators

**NEED INTEGRATED PROGRAM**

For more information

www.avocadosource.com

- Variety information
- Database of avocado varieties
- Information on rootstocks (ongoing)