Replant Disease-Resistant Rootstocks

Terence Robinson, Gennaro Fazio, Herb Aldwinckle

Dept. of Horticulture, Cornell University, Geneva, New York, 14456
USDA-ARS, Plant Genetics Resources Unit, Geneva, NY 14456
Keys to Successful New Apple Orchards

• Plant high-tree densities (optimum ~3,000 trees/ha).
• Produce high early yields (150 t/ha over the first 5 years).
• Grow the trees rapidly to fill the allotted space in the first 3 years.
• Produce high mature yields (>60 t/ha) of high quality fruit.

• Poor tree growth due to replant disease in the first 3 years jeopardizes the economic success of the new orchard.
Strategies to Overcome Apple Replant Disease

- Soil fumigation
  - Expensive
  - Environmental concerns
  - Short duration of effect
- Soil amendments
  - Limited effectiveness
  - Expensive
- Replacing soil
  - Expensive
  - Labor intensive
- Genetic tolerance or resistance of rootstock
  - Effective for life of orchard
  - Inexpensive
The Geneva Apple Rootstock Breeding and Development Program

Cornell University Program 1968-2008
Dr. James Cummins and Herb Aldwinckle

Joint Program with USDA and Cornell University (1998-present)
Dr. Gennaro Fazio, Herb Aldwinckle and Terence Robinson

Goal: Produce a series of dwarfing rootstocks which are resistant to important rootstock diseases and insects.

- Resistance to fire blight
- Resistance to *Phytophthora* root rot
- Resistance to woolly apple aphid
- Cold tolerant
- Resistance to apple replant disease.
# Tolerance of Geneva® Stocks to Replant Disease

(Empire Experiment, NY 1991)

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>Relative Tree Vigor (Virgin Site (% of M.7))</th>
<th>Relative Growth at Replant Site (% of Virgin site)</th>
<th>Replant Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.7</td>
<td>100</td>
<td>+1</td>
<td>Tolerant</td>
</tr>
<tr>
<td>M.26</td>
<td>72</td>
<td>-30</td>
<td>Highly Susceptible</td>
</tr>
<tr>
<td>G.210</td>
<td>66</td>
<td>+8</td>
<td>Tolerant</td>
</tr>
<tr>
<td>G.30</td>
<td>60</td>
<td>+5</td>
<td>Tolerant</td>
</tr>
<tr>
<td>G.935</td>
<td>51</td>
<td>-3</td>
<td>Mod Tolerant</td>
</tr>
<tr>
<td>G.202</td>
<td>43</td>
<td>+21</td>
<td>Tolerant</td>
</tr>
<tr>
<td>M.9</td>
<td>39</td>
<td>-8</td>
<td>Mod. Susceptible</td>
</tr>
<tr>
<td>G.41</td>
<td>36</td>
<td>-4</td>
<td>Mod. Tolerant</td>
</tr>
<tr>
<td>B.9</td>
<td>26</td>
<td>+3</td>
<td>Tolerant</td>
</tr>
</tbody>
</table>
Growth of Un-grafted Stocks in a Pasteurized and a Replant Soil

Data redrawn from Isutsa and Merwin 2000
Geneva Replant Disease Evaluation of 38 Genotypes

Kviklys et al
Rootstock Tolerance to Replant Disease in Potted Trees

% Increase in Growth due to Pasteurization

Kviklys et al
Field Performance of G.4210 and G.202 in New Zealand

(White et al., 2002)
Field Tolerance to Replant Disease at 8 Locations in North America

Robinson et al.

% Increase in TCA due to Fumigation

Gala Production Response to Fumigation in North America

% Increase due to Fumigation

TCA  Cum. Yield Efficiency
What is the definition of a Resistant Rootstock?

- Traditionally resistance has been defined as similar growth in pasteurized soil and replant soil.

- However, field trials show that even resistant rootstocks respond to fumigation with improved yield compared to un-fumigated controls.

- Even if a rootstock can grow well in replant disease soil there appears to be a cost in yield likely due to the need to invest more carbohydrate resources into root growth and less into fruit growth.
Growth of Gala in a Replant Soil
Washington State

Wapato 2004 Gala

Data from Auvil et al. 2010
Growth of Gala in a Replant Soil

Washington State

Data from Auvil et al. 2010
Yield of Gala in a Replant Soil
Washington State

Wapato 2004 Gala Rootstock

Yield (ton)

- Fum 2007
- Fum 2006
- Non-fum 2007
- Non-fum 2006

Data from Auvil et al. 2010
Early Yield Improvement of Gala due to Fumigation in a Replant Soil
Washington State

Data from Fazio
Growth of Gala in a Replant Soil
Washington State

Chelan 2004 Gala

Data from Auvil et al. 2010
Growth of Gala in a Replant Soil
Washington State

Data from Auvil et al. 2010
Yield of Gala in a Replant Soil
Washington State

Mean Cumulative Yield Per Tree (2006-2007) CHELAN

Data from Fazio
Yield of Gala in a Replant Soil
Washington State

Mean Cumulative Yield of Highest and Lowest Three Rootstocks

Highest Three
- G.935
- G.41
- G.16

Lowest Three
- B.9
- Supp.2
- Supp.1

Data from Fazio
Yield of Gala in a Replant Soil
Washington State

'D06 Wapato Gala Yield 2007 to 2011

Data From Auvil et al. 2012
Yield Increase of Gala in a Replant Soil
Washington State

Data From Auvil et al. 2012
Growth of Fuji in a Replant Soil
Washington State

Data From Auvil et al. 2010

'06 Vantage Fuji TCSA 2011

Trunk Cross Sectional Area (cm²)

Data From Auvil et al. 2010
Growth of Fuji in a Replant Soil
Washington State

Data From Auvil et al. 2010
## Summary of Replant Resistance Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>G.11</th>
<th>G.41</th>
<th>G.214</th>
<th>G.935</th>
<th>G.210</th>
<th>G.30</th>
<th>M.9</th>
<th>M.26</th>
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<tbody>
<tr>
<td>Robinson 1991</td>
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<td>T</td>
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<td>T</td>
<td>R</td>
<td>R</td>
<td>S</td>
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<tr>
<td>Isutsas 2000</td>
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<td>--</td>
<td>R</td>
<td>R</td>
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<tr>
<td>Laurent 2010</td>
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<td>R</td>
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<tr>
<td>Kviklys 2012</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>T</td>
<td>--</td>
<td>R</td>
<td>S</td>
<td>S</td>
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<tr>
<td>White 2000</td>
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<td>R</td>
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<tr>
<td>Robinson 2012</td>
<td>T</td>
<td>R</td>
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<td>T</td>
<td>T</td>
<td>R</td>
<td>T</td>
<td>S</td>
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<tr>
<td>Auvil 2010 (Wapato)</td>
<td>T</td>
<td>R</td>
<td>T</td>
<td>R</td>
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<td>T</td>
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<tr>
<td>Auvil 2010 (Chelan)</td>
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<tr>
<td><strong>Average</strong></td>
<td>T</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>S</td>
<td>S</td>
</tr>
</tbody>
</table>
G.11

- Tree size similar to M.9 T337.
- Productivity is similar to M.9.
- Large fruit size
- Tolerant to Replant Disease
- Resistant to Fire Blight but not immune.
- Resistant to Crown Rot
- Not tolerant to replant disease
- Susceptible to Wooly Apple Aphid
- Good rooting in stoolbed

Courtesy of Stefano Musacchi
G.41

- M.9 vigor
- Highly yield efficient
- Highly productive
- Very precocious
- Resistant to replant disease
- Very cold hardy
- Does well in warmer climates (Mexico)
- Immune to Fire Blight and Crown Rot and Wooly Apple Aphid
- Requires tissue culture mother plants for stoolbed
G.214

- Vigor similar to M.9 Pajam2
- Highly yield efficient
- Highly productive
- Good precocity
- Tolerant to replant disease
- Resistant to Fire Blight, Crown Rot and Wooly Apple Aphid
- Very good stool bed propagation
- No commercial production of liners.
G.935

- Vigor intermediate between M.9 Pajam 2 and M.26
- Very cold hardy
- Resistant to Replant Disease
- Resistant to Fire Blight and Crown Rot
- Tolerant to Replant Disease Complex
- Susceptible to Wooly Apple Aphid
- Production in US ~50,000 plants in 2011.
G.202

- It is similar in size to M.26
- Precocious, productive
- It is resistant to woolly apple aphid, fire blight, and crown rot
- In New Zealand it has been a top performer
- Good choice for weak growing cultivars like Honeycrisp
- Tolerant to apple replant disease
- Moderate rooting in stoolbed
G.210

- Vigor between M.7 and MM.106
- Precocious, productive
- Yield efficiency similar or better than M.9
- Resistant to apple replant disease.
- Resistance to woolly apple aphid, fire blight, and crown rot.
- Good rooting in stoolbed few spines.
- Mostly for Organic Production
Released Geneva® Apple Rootstocks Arranged by Tree Size

M.27 Size
- G.65
- G.11
- G.41
- G.16

M.9 T337
- M.9 PAJ 2
- M.26 Size
- G.935
- G.202
- M.7-MM106 Size
- G.214
- G.969
- G.210
- G.890
- Seedling Size
- G.222
- G.213

New Releases
Summary

- Several Geneva® rootstocks appear to have tolerance/resistance to apple replant disease.
  - G.41
  - G.214
  - G.935
  - G.202
  - G.210

- The resistance may be due to the initial screening for Phytophthora disease which may also have selected for tolerance to other soil microorganisms.

- Resistant rootstocks show an improvement in yield due to fumigation.

- The variation around the world in soil organisms which cause apple replant disease may result in variable orchard results with the resistant rootstocks.
Questions?