Apple Rootstock Update
2017 Great Plains Growers Conference

Matt Stasiak
Peninsular Agricultural Research Station
UW-Madison CALS
Current Plantings
2015 Organic Apple Rootstock
2014 Apple Rootstock
2010 Apple Rootstock

Completed plantings
2006 Apple Replant
2003 Apple (Golden Delicious) Physiology
2003 Dwarf Apple Rootstock
2002 Apple (Gala) Rootstock
2002 New Jersey-Massachusetts Cameo
1999 Dwarf Apple (Fuji and McIntosh) Rootstock
1999 Semi-dwarf Apple Rootstock
1998 G.16 Apple Rootstock
1994 Gala Dwarf Apple Rootstock
1994 Gala Semi-dwarf Apple Rootstock
1992-1993 Liberty/CG Apple Rootstock
1990 Apple Systems
1990 Gala Apple Rootstock
1990 Apple Cultivar/Rootstock Apple
1984 Apple (Red Delicious) Rootstock
1980/81 Apple (Red Delicious) Rootstock
<table>
<thead>
<tr>
<th>Code</th>
<th>Name</th>
<th>Code</th>
<th>Name</th>
<th>Code</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMLA 7</td>
<td></td>
<td>EMLA 26</td>
<td></td>
<td>OAR 1</td>
<td></td>
</tr>
<tr>
<td>EMLA 9</td>
<td></td>
<td>MARK</td>
<td></td>
<td>OTT 3</td>
<td></td>
</tr>
<tr>
<td>M 9</td>
<td></td>
<td>EMMA 27</td>
<td></td>
<td>MAC 24</td>
<td></td>
</tr>
<tr>
<td>M.9</td>
<td></td>
<td>V.1</td>
<td></td>
<td>V.3</td>
<td></td>
</tr>
<tr>
<td>V.5</td>
<td></td>
<td>V.6</td>
<td></td>
<td>V.7</td>
<td></td>
</tr>
<tr>
<td>V.1</td>
<td></td>
<td>G.11</td>
<td></td>
<td>G.30</td>
<td></td>
</tr>
<tr>
<td>V.3</td>
<td></td>
<td>G.202</td>
<td></td>
<td>G.41</td>
<td></td>
</tr>
<tr>
<td>V.5</td>
<td></td>
<td>G.16N</td>
<td></td>
<td>G.16T</td>
<td></td>
</tr>
<tr>
<td>V.6</td>
<td></td>
<td>M.9</td>
<td></td>
<td>M.9</td>
<td>T337</td>
</tr>
<tr>
<td>V.7</td>
<td></td>
<td>CG.4013</td>
<td></td>
<td>CG.4003</td>
<td></td>
</tr>
<tr>
<td>C 935</td>
<td></td>
<td>CG.4004</td>
<td></td>
<td>CG.4003</td>
<td></td>
</tr>
<tr>
<td>C 210</td>
<td></td>
<td>CG.4013</td>
<td></td>
<td>CG.4003</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CG.4214</td>
<td></td>
<td>CG.5087</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CG.4814</td>
<td></td>
<td>CG.5222</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CG.5087</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>G.969</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pajam 1</td>
<td></td>
<td>G.890</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pajam 2</td>
<td></td>
<td>G.65</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-9</td>
<td>V-605-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-491</td>
<td>G.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V-605-1</td>
<td></td>
<td>CG13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-2</td>
<td>G.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-16</td>
<td>CG 179</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-22</td>
<td>G.202</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-64-194</td>
<td></td>
<td>G.41</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-67-5-32</td>
<td></td>
<td>G.16N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B.10</td>
<td>G.16T</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B.64-194</td>
<td></td>
<td>M.9</td>
<td></td>
<td></td>
<td>T337</td>
</tr>
<tr>
<td>B.70-6-8</td>
<td></td>
<td>CG 179</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B.70-20-20</td>
<td></td>
<td>G.202</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B.7-20-21</td>
<td></td>
<td>G.41</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B.71-7-22</td>
<td></td>
<td>G.16N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B.7-3-150</td>
<td></td>
<td>G.16T</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supporter 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supporter 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supporter 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supporter 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CG 707</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CG.3041</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CG.5935</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J-TE-H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PiAu 51-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PiAu 56-83</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bud.62-396</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CG.2034</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CG.3001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CG.4003</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.969</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.890</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.65</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Over the millennia since the apple’s domestication, growers had tried to exploit spontaneously occurring genetic mutations that made the trees shorter and thus easier to harvest, grafting the best fruiting varieties onto these cloned dwarfing rootstocks.
History - Selection

1900’s Dawn of the Modern Apple Rootstock

‘M’ Series
Malling
M.1 through M.27

‘Sir’ Ronald Hatton

EM VII
OR
M.7

‘Sir’ Thomas Neame

M.9
History - Early Breeding

1920’s
‘MM’ Malling-Merton
Malling x Northern Spy
Woolly Apple Aphid resistant

MM.106 & MM.111

Photo credit: E. Beers, June 2009, Washington State University
History - Improvement

1960’s
‘EMLA’ East Malling & Long Ashton Stations

Removed viruses
Slightly more vigorous than M’s
EMLA 9, EMLA 26, etc.

Photos: Mid-Atlantic Orchard Monitoring Guide
History - The Potential

Lower cost per unit of production
High quality fruit and greater % pack-out
Earlier return on investment
Regular & annual production
Quicker & easier adjustment to change
Ability to adjust to various stresses

H.B Tukey 1964
“Although M.9 has many favorable characteristics, it has some problems, such as poor anchorage in the soil, propagation difficulty, winter injury, brittle roots, and susceptibility to fireblight and crown gall.”

“Therefore new dwarfing rootstocks without the shortcomings of M.9 are desirable.”
M.9 ‘Type’

• Bud. 9
• M.9 NAKB 337
• M.9 EMLA
• M.9 Nic RN29

Supporter Series (GER)
Geneva Series (USA)
Budagovski (RUS)
Vineland (CAN)
Polish
Etc…
NC140

Evaluated for
survival
precocity
productivity
size control
anchorage
suckering
pest resistance
adaptability
production efficiency

Trials concluded after 8-10 growing seasons.

Data collected
root suckering
tree growth trunk cross-sectional area
tree height & spread
precocity
yield
yield efficiency
fruit size
Maximizing the Potential

- Fruit Quality
- Nursery Production
- Hardiness
- Pest Resistance

Efficiency
Estimating Tree Size

Trunk Cross Sectional Area vs. diameter or circumference

\[ \Pi r^2 = \text{Area} \]
Estimating Tree Size

\[DW = -4.25 + 0.41 \text{TCSA}\]

\[R^2 = 0.92\]
Measuring Efficiency

\[ \text{‘YE’} = \frac{\text{YIELD}}{\text{TCSA}} \]

YIELD
Production (kg)

TCSA
Tree Size (cm\(^2\))
Measuring Efficiency

1990 NC140 Cultivar/Rootstock Trial
Ten year cumulative average for 12 sites

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>TCSA (cm²)</th>
<th>Yield/Tree (kg)</th>
<th>Yield Efficiency (kg/cm² TCSA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mark</td>
<td>46</td>
<td>127</td>
<td>2.9</td>
</tr>
<tr>
<td>B.9</td>
<td>57</td>
<td>152</td>
<td>3.0</td>
</tr>
<tr>
<td>M.9 EMLA</td>
<td>88</td>
<td>195</td>
<td>2.5</td>
</tr>
<tr>
<td>M.26 EMLA</td>
<td>118</td>
<td>210</td>
<td>2.0</td>
</tr>
</tbody>
</table>

‘YE’ = \( \frac{\text{YIELD}}{\text{TCSA}} \)

\( \text{YIELD} = \) Production (kg)

\( \text{TCSA} = \) Tree Size (cm²)
Tree Size

Yield Efficiency vs. Tree Size

- Cumulative yield efficiency (kg/cm² trunk cross-sectional area)
- Trunk cross-sectional area (cm²)

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>TCSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.9</td>
<td>&lt; M.9</td>
</tr>
<tr>
<td>G.41</td>
<td>= M.9</td>
</tr>
<tr>
<td>G.16</td>
<td>= M.26</td>
</tr>
<tr>
<td>G.935</td>
<td>= M.26</td>
</tr>
<tr>
<td>M.9 Pajam 2</td>
<td>= M.26</td>
</tr>
<tr>
<td>M.9 T337</td>
<td>= M.26</td>
</tr>
<tr>
<td>B.62396</td>
<td>= M.26</td>
</tr>
<tr>
<td>J-TE-H</td>
<td>= M.26</td>
</tr>
<tr>
<td>M.26</td>
<td>= M.26</td>
</tr>
<tr>
<td>PiAu51-4</td>
<td>= M.26</td>
</tr>
<tr>
<td>PiAu 56-83</td>
<td>= M.26</td>
</tr>
</tbody>
</table>

2003 NC140, Sturgeon Bay
< 30% Full Sun

- Low Flower Production
- Poor Fruit Quality
Better Light Distribution!

Dwarfing Rootstocks

7-8’

5-6’
Earlier Return on Investment

1999 NC140 Apple Rootstock, Sturgeon Bay
Earlier Return on Investment

Tree density

Establishment cost & payback

<table>
<thead>
<tr>
<th>Tree density</th>
<th>1500-2000</th>
<th>800-1000</th>
<th>500-600</th>
<th>250-300</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super high</td>
<td>$20,000</td>
<td>$15,000</td>
<td>$10,000</td>
<td>$2,500 - $3,000</td>
</tr>
<tr>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
<th>20</th>
</tr>
</thead>
</table>
20 Year Profit Estimate

$100,000
$80,000
$60,000
$40,000
$20,000
$0
$-20,000
$-40,000

0 5 10 15 20

Central Leader
Vertical Axe
Tall Spindle
Super Spindle
## Spur Quality and Canopy Position

<table>
<thead>
<tr>
<th>Canopy Position</th>
<th>% Full Sunlight</th>
<th>Spur Dry Weight (g/spur)</th>
<th>% Fruit Set</th>
<th>% Red Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top</td>
<td>48</td>
<td>0.98</td>
<td>61</td>
<td>88</td>
</tr>
<tr>
<td>Middle</td>
<td>23</td>
<td>0.87</td>
<td>54</td>
<td>80</td>
</tr>
<tr>
<td>Bottom</td>
<td>9</td>
<td>0.62</td>
<td>42</td>
<td>81</td>
</tr>
</tbody>
</table>

% Reduction from top to bottom: -80%, -37%, -31%, -8%

Fruit Size and Canopy Position

Budagovski

- Breeding program at Michurinski College in Russia.
- Resistance to low temperature stress.
- **B9** an ‘M.9’ replacement in cold climates.
  
  *M.8 x Red Standard (Krasnij Standart)*

- 2003 planting: **B10** (B62-396) tested.
- 2010 planting: **B9, B10, B64-194, B67-5-32, B70-6-8, B70-20-20, B7-20-21, B71-7-22, B7-3-150.**
- 2014 planting: **B10 & Vineland series (CAN)**
2012-13 Winter Injury - Root Damage

From about 3 inches below the surface

From about 8 inches below the surface

THIS IS B.9!
2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F

2013
January
February

Minimum soil Temperature @ 4"

Minimum Air Temperature

°F
2013
January
February

- Minimum soil Temperature @ 4"
- Minimum Air Temperature

°F

January
February

1/1 1/8 1/15 1/22 1/29 2/5 2/12 2/19 2/26

Graph showing minimum soil and air temperatures for January and February 2013.
Minimum soil Temperature @ 4"
Minimum Air Temperature
Snow Cover

2013
January
February

Snow depth
inches
Breeding and Developing New Apple Rootstocks

Started in 1968 Geneva, NY

Goals:
• Resistant to Fireblight
• Resistant to Phytophthora
• Resistant to Wooly Apple

As productive and precocious as Malling stocks

Dr. Jim Cummins
Fireblight
G & CG (Geneva and Cornell Geneva)

- Cornell-Geneva breeding program located in Geneva, NY, USA.
- Selected for horticultural characteristics and resistance to fire blight, crown rot & WAA.
- G released to the commercial market.
  Earlier releases - G11, G16, G41, G935, G202, G30
  Recent releases - G213, G214, G814, G969, G210, G890
- CG are still in test.
  - CG.2034, CG.3001, CG.4003, CG.4004, CG.4013, CG.5087, CG.5222 etc....
Released GENEVA® Apple Rootstocks
Arranged by Tree Size

M.27 Size
M.9 T337
M.9 PAJ 2
M.26
M.7-MM106

Seedling Size

G.65
G.11
G.41
G.214
G.935
G.969

G.16
G.814
G.222
G.202
G.30
G.210

G.213
G.890

New Releases

The GENEVA® Apple Rootstocks perform differently in Washington State conditions in comparison to the data displayed here that was collected in New York State.

Please contact your local extension agent for growing predictions for these varieties in your region.
2010 NC140 Apple Rootstock, Wisconsin
- Yield Efficiency
<table>
<thead>
<tr>
<th>Rootstock</th>
<th>Fireblight Resistance</th>
<th>Crown Rot Tolerance</th>
<th>Wooly Apple Aphid</th>
<th>Replant Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.11</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>G.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.41</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

G.16 is hypersensitive to at least one latent virus.
<table>
<thead>
<tr>
<th>NC-140 Trial</th>
<th>Tree Size TCA (% of M.9)</th>
<th>Yield Eff. (% of M.9)</th>
<th>Fruit Size (% of M.9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996 Gala</td>
<td>150*</td>
<td>124*</td>
<td>109*</td>
</tr>
<tr>
<td>1998 Jonagold</td>
<td>96</td>
<td>155*</td>
<td>93*</td>
</tr>
<tr>
<td>1999 McIntosh</td>
<td>126</td>
<td>124</td>
<td>105</td>
</tr>
<tr>
<td>2003 Goldens-WI</td>
<td>70 *</td>
<td>120*</td>
<td>91*</td>
</tr>
<tr>
<td>2010 Honeycrisp</td>
<td>106</td>
<td>103</td>
<td>107*</td>
</tr>
</tbody>
</table>
G.41 - vigor like larger M.9 clones (NIC29)

Resistant to Fire Blight and Crown Rot
Resistant to Wooly Apple Aphid
Tolerant to Replant Disease Complex
  • Very precocious
  • Very cold hardy
  • Tends to be less biennial on Honeycrisp.
  • In the USA new stoolbeds planted in 2009 and 2010.
## M.9

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>Fireblight Resistance</th>
<th>Crown Rot Tolerance</th>
<th>Wooly Apple Aphid</th>
<th>Replant Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.11</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>G.16</td>
<td>Hypersensitive to at least one latent virus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.41</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Rootstock</td>
<td>Fireblight Resistance</td>
<td>Crown Rot Tolerance</td>
<td>Wooly Apple Aphid</td>
<td>Replant Tolerance</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------</td>
<td>---------------------</td>
<td>-------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>G.11</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>G.16</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td><strong>Hypersensitive to at least one latent virus</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.41</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>B.10</td>
<td>✓</td>
<td>✓</td>
<td>?</td>
<td>✓</td>
</tr>
<tr>
<td>G.213</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>G.214</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>G.814</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
</tr>
</tbody>
</table>
### 2010 NC140 Apple Rootstock, Sturgeon Bay

**Rootstock** | **Yield Efficiency (kg/cm² TCSA)**
--- | ---
M.9 T337 | 3.0
G.11 | 3.4*
B.10 | 3.2*
G.41 | 3.1
G.213 | ??

**Rootstock** | **Yield Efficiency (kg/cm² TCSA)**
--- | ---
G.214 | 3.2*
G.814 | 2.6*
M.26 EMLA | 2.4

$1,000 - $5,000/A
<table>
<thead>
<tr>
<th>Rootstock</th>
<th>Fireblight</th>
<th>Crown Rot</th>
<th>Wooly Apple Aphid</th>
<th>Replant Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.935</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>G.202</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>G.222</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
</tr>
</tbody>
</table>
**G.935** - vigor slightly smaller than M.26

Resistant to Fire Blight and Crown Rot

**Susceptible** to Wooly Apple Aphid

Tolerant to Replant Disease Complex

- More productive than M.26, like M.9.
- Very cold hardy.
- Fruit size is smaller than M9 in some trials; **not in WI**.

Questions about compatibility/latent virus?
<table>
<thead>
<tr>
<th>NC-140 Trial</th>
<th>Tree Size TCA (% of M.9)</th>
<th>Yield Eff. (% of M.9)</th>
<th>Fruit Size (% of M.9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991 Empire</td>
<td>138 *</td>
<td>122</td>
<td>---</td>
</tr>
<tr>
<td>1998 Gala</td>
<td>207 *</td>
<td>112 *</td>
<td>101</td>
</tr>
<tr>
<td>1999 Mcintosh</td>
<td>177*</td>
<td>111</td>
<td>95</td>
</tr>
<tr>
<td>2010 Honeycrisp</td>
<td>116*</td>
<td>122*</td>
<td>100</td>
</tr>
</tbody>
</table>
G.202 - vigor similar to M.26

Resistant to Fire Blight and Crown Rot
Resistant to Wooly Apple Aphid
Tolerance to Replant Disease Complex
• Precocious, productive.
• Cold hardy.
• Good choice for weak growing cultivars like Honeycrisp.
<table>
<thead>
<tr>
<th>NC-140 Trial</th>
<th>Tree Size TCA (% of M.9)</th>
<th>Yield Eff. (% of M.9)</th>
<th>Fruit Size (% of M.9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991 Empire</td>
<td>153*</td>
<td>101</td>
<td>---</td>
</tr>
<tr>
<td>1996 Delicious</td>
<td>171*</td>
<td>103</td>
<td>108*</td>
</tr>
<tr>
<td>1999 McIntosh</td>
<td>200*</td>
<td>76*</td>
<td>101</td>
</tr>
<tr>
<td>2010 Honeycrisp</td>
<td>120</td>
<td>93</td>
<td>96</td>
</tr>
<tr>
<td>Rootstock</td>
<td>Fireblight</td>
<td>Crown Rot</td>
<td>Wooly Apple Aphid</td>
</tr>
<tr>
<td>-----------</td>
<td>------------</td>
<td>-----------</td>
<td>-------------------</td>
</tr>
<tr>
<td>G.30</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
</tr>
<tr>
<td>G.210</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>G.969</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>G.890</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

‘YE’ > M.26!!
2010 NC140 Apple Rootstock, Wisconsin

B.9  M.9  M.26  M.7
2010 NC140 Apple Rootstock, Wisconsin
- Yield Efficiency
2010 NC140 Apple Rootstock, Wisconsin
- Yield Efficiency

![Bar chart showing yield efficiency for various rootstocks.](image-url)
2010 NC140 Apple Rootstock, Wisconsin
- Yield Efficiency
<table>
<thead>
<tr>
<th>Traits</th>
<th>D1148</th>
<th>D1147</th>
<th>D3610</th>
<th>D3539</th>
<th>D4950</th>
<th>D6263</th>
<th>D3609</th>
<th>D4190</th>
<th>D2737</th>
<th>D4951</th>
<th>D3785</th>
<th>D3540</th>
<th>D5107</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arranged in order by size (smallest to largest)</td>
<td>M.9 T337</td>
<td>M.9 T337</td>
<td>M.9 T337</td>
<td>M.9 T337</td>
<td>M.9/M.26</td>
<td>M.26</td>
<td>M.26</td>
<td>M.26</td>
<td>M.7</td>
<td>M.7</td>
<td>M.7</td>
<td>M.7</td>
<td>M.7/MM.108</td>
</tr>
<tr>
<td>Woolly Apple Aphid Resistance</td>
<td>No</td>
<td>No</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>No</td>
<td>No</td>
<td>High</td>
<td>High</td>
<td>No</td>
<td>High</td>
<td>No</td>
<td>High</td>
</tr>
<tr>
<td>Fire Blight Resistance</td>
<td>Resistant</td>
<td>Very Resistant</td>
<td>Very Resistant</td>
<td>Very Resistant</td>
<td>Very Resistant</td>
<td>Very Resistant</td>
<td>Very Resistant</td>
<td>Very Resistant</td>
<td>Very Resistant</td>
<td>Very Resistant</td>
<td>Very Resistant</td>
<td>Very Resistant</td>
<td></td>
</tr>
<tr>
<td>Replant Disease Complex Resistance</td>
<td>Partial</td>
<td>Partial</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td>No</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td>Tolerant</td>
</tr>
<tr>
<td>Crown and Root Rot (Phytophthora)</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td></td>
</tr>
<tr>
<td>Cold Hardiness</td>
<td>Yes</td>
<td>Partial: Good Midwinter, Bad early cold</td>
<td>Yes</td>
<td>TBD</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Productivity/Yield Efficiency-as good or better than M.9</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Low suckering and burr knots</td>
<td>TBD</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Susceptibility to latent viruses</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

TBD: To Be Determined.
(a) Remarks: G.41 has presented weak graft unions with the following scions: Cripps Pink, Scilate, and Honeycrisp. The well feathered trees are prone to breakage in strong winds in the first 2-3 years and additional care needs to be taken to prevent breakage. Breakage risk decreases with time.
Recommendation: Use plant materials that have been tested and are “clean” of viruses.
Licensing for all varieties is available as exclusive or non-exclusive in selected Domestic and International Territories.

Chart data valid as of July 22, 2016, and supplied by Cornell University apple rootstock breeding team members, Gennaro Fazio, PhD., USDA Breeder, Terence Robinson, PhD, Cornell Breeder, and Herb Aldwinckle, PhD, Professor Emeritus.
Only Part of the Matrix

- Fruit Quality
- Nursery Production
- Pest Resistance
- Hardiness Efficiency

Operational Efficiency
Better Light Distribution & Use Efficiency!

Slender Spindle & Central Leader

Vertical Axis

Tall Spindle

6-7’

6-7’

4’
Early Yields – Honeycrisp, NY
Modern Apple Training Systems. 2005, Robinson

Bushels / Acre

<table>
<thead>
<tr>
<th></th>
<th>Slender Spindle</th>
<th>Vertical Axis</th>
<th>Tall Spindle</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd</td>
<td>0</td>
<td>2nd .1</td>
<td>2nd 3</td>
</tr>
<tr>
<td>3rd</td>
<td>33</td>
<td>3rd 111</td>
<td>3rd 132</td>
</tr>
<tr>
<td>4th</td>
<td>117</td>
<td>4th 277</td>
<td>4th 578</td>
</tr>
<tr>
<td>Cum.</td>
<td>150</td>
<td>Cum. 388</td>
<td>Cum. 713</td>
</tr>
</tbody>
</table>

2nd 200
3rd 500
4th 800
Cum. 1,500

2nd 444 T/A
3rd 726 T/A
4th 908 T/A
2010 NC140 Apple Rootstock - Wisconsin

Density: 908 T/A

Bushels / Acre:
- M.9T337:
  - 2nd: 0
  - 3rd: 479
  - 4th: 568
  - Cum.: 1,047
- G935:
  - 2nd: 0
  - 3rd: 359
  - 4th: 1061
  - Cum.: 1,420
- CG4004:
  - 2nd: 0
  - 3rd: 563
  - 4th: 1264
  - Cum.: 1,827
What is a Tall Spindle?

Optimum Economic Density
900 - 1,200 trees/acre

High Early Production
*Feathered trees, minimal pruning & branch tying*
Cumulative yield 1,500 bu/a first 4 years

High Mature Yields (5+ yrs.)
*High light interception 70-75%*
Sustained yields of 1,200 - 1,500 bu/a

High Fruit Quality
*Good light distribution in the canopy*
Thin conical canopy
No permanent branches
Simplified (columnarized) fruiting branches
Balance vigor ‘calm trees’

Improved Labor Efficiency
*Simplified pruning steps*
Possible mechanization of dormant pruning
Mechanized summer hedging
Tall Spindle

• Closer in-row spacing of 3' for weak growing varieties (Honeycrisp)

• In-row spacing of 4' for vigorous varieties and tip bearing varieties. (McIntosh, Fuji, Gala, Gingergold)

• Between row 10-12’

• Tree Height = 10-11’
Simple Pruning Steps for Mature Tall Spindle

1. Limit tree height by cutting leader back to fruitful side branch.

2. Remove 2-3 large branches (>3/4”)  
   “large branches create large trees”

3. Simplify or ‘columnarize’ remaining branches so a single axis is left
Branch Growth Progression and Pruning

1 Yr.

2 Yr.

3 Yr.

4 Yr. ‘columnarize’

5 Yr. ‘shorten’

‘renew’
Mechanical Pruning Mature Tall Spindle?

Benefits
- Reduced pruning costs \( \frac{1}{2} \)
- Improved fruit quality

Goal
- Narrow fruiting wall
- Good light distribution
- Avoid vigorous response

1yr & 2yr hedge
3yr corrective pruning
  - remove large caliper
  - ‘crows feet’
Tall Spindle Common Mistakes

Biggest mistakes:
Not tying initial branches down
Excessive cropping years 2-4
Not growing tree to top wire fast enough
Retaining too many large branches on mature trees

“This!”

“large branches create large trees”
Tall Spindle Common Mistakes

Avoid excessive cropping in the first 5 years

4 fruit/cm² TCSA biennial varieties (Honeycrisp)

5 fruit/cm² TCSA non-biennial varieties

YEAR - #FRUIT

1.............0
2.............20
3.............40
4.............80
5.............100

Hand Thinning Gauge - Apples
WI Funding for NC140 Plantings

Door & Kewaunee County

2014 & 2015 Planting
# Current and Future PARS

## 2010 NC140 Apple

<table>
<thead>
<tr>
<th>Russia</th>
<th>USA - advanced</th>
<th>USA - commercial</th>
<th>Germany</th>
<th>CONTROLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.9</td>
<td>CG.2034</td>
<td>G.11</td>
<td>PiAu 51-11</td>
<td>M.9T337</td>
</tr>
<tr>
<td><strong>Bud 10</strong> (62-396)</td>
<td>CG.3001</td>
<td><strong>G.41 Normal</strong></td>
<td>PiAu 9-90</td>
<td><strong>M.9Pajam2</strong></td>
</tr>
<tr>
<td>Bud 64-194</td>
<td>CG.4003</td>
<td><strong>G.41 TC</strong></td>
<td>Supporter 3</td>
<td><strong>M.26EMLA</strong></td>
</tr>
<tr>
<td>Bud 67-5-32</td>
<td>CG.4004</td>
<td>G.935 Normal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bud 70-6-8</td>
<td>CG.4013</td>
<td>G.935 TC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bud 70-20-20</td>
<td>CG.4214</td>
<td><strong>G.202 Normal</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bud 70-20-21</td>
<td>CG.4814</td>
<td><strong>G.202 TC</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bud 71-7-22</td>
<td>CG.5087</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bud 7-3-150</td>
<td>CG.5202 (222)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Current and Future PARS

2014 NC140 Apple

<table>
<thead>
<tr>
<th>Russia</th>
<th>USA</th>
<th>Canada</th>
<th>CONTROLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.10</td>
<td>G.11</td>
<td>V.1</td>
<td>M.26 EMLA</td>
</tr>
<tr>
<td>G.202</td>
<td></td>
<td>V.5</td>
<td>M.9 T337</td>
</tr>
<tr>
<td>G.214</td>
<td></td>
<td>V.6</td>
<td></td>
</tr>
<tr>
<td>⭐️ G.30</td>
<td></td>
<td>V.7</td>
<td></td>
</tr>
<tr>
<td>G.41</td>
<td>⭐️ G.5890</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.935</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>⭐️ G.969</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Vineland (‘V.’) series

- Dr. Aleck Hutchinson
- Horticultural Experiment Station Canada, Vineland Station in 1958.
- Open-pollinated hybrids of ‘Kerr’ crabapples x M.9 rootstock
- Dwarf growth habit, cold hardiness, ease of propagation, and disease and insect resistance. Resistance to low temperature stress.

Size Class

- V.5 & V.6 ≤ M.9
- V.3 = M.9
- V.1 & V.2 = M.26
- V.7 = M.7
2010 NC140 Apple Rootstock Estimated per Acre Yield Comparison

- cg4004
- g935
- m9

Yield bu/a

<table>
<thead>
<tr>
<th>Year</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>6th</th>
<th>7th</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Maximizing the Potential

- Fruit Quality
- Nursery Production
- Hardiness
- Pest Resistance

Efficiency
Google:
NC140 rootstock
-or-
Geneva rootstock