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# 'Gala' Apple Trees on Supporter 4, P.14, and Different Strains of B.9, M.9 and M.26 Rootstocks: Final 10-Year Report on the 2002 NC-140 Apple Rootstock Trial

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**Additional index words:** fruit weight, tree size, yield, yield efficiency


## Abstract

In 2002, an orchard trial of apple rootstocks was established at six locations in Canada, Mexico, and the United States using 'Buckeye Gala' as the scion cultivar. Rootstocks included B.9 (North American strain), B.9 (European strain), M.26 NAKB, M.26 EMLA, M.9 Burgmer 756, M.9 Nic 29, M.9 NAKBT337, P.14, and Supporter 4. After 10 years, the greatest mortality was for trees on Supporter 4 (35%), and the lowest was for trees on M.26 NAKB (10%) and B.9 Europe (7%). P.14 resulted in the largest trees based on trunk cross-sectional area (TCA). Smallest trees were on the two B.9 strains. Largest trees in the intermediate group were on M.9 Burgmer 756, followed by those on Supporter 4, and M.26 NAKB, M.26 EMLA, M.9 NAKBT337, and M.9 Nic 29. Burr knot severity was highest on M.26 NAKB and lowest on B.9 North America, M.9 Burgmer 756, and M.9 Nic 29. Root suckering was greatest from trees on M.9 Nic 29, more than all other rootstocks. B.9 Europe produced significantly more root suckers than did B.9 North America. Trees on P.14, M.9 Burgmer 756, M.26 NAKB, and M.9 NAKBT337 yielded more (cumulatively, 2004-11) than did those on either strain of B.9. The most yield efficient trees (cumulatively, 2004-11) were on the two B.9 strains, and the least efficient trees were on P.14. On average over the first 8 years of fruiting, the M.9 strains resulted in larger fruit than did the B.9 strains. B.9 North America resulted in significantly larger fruit than did B.9 Europe. Additional rootstocks tested at a small number of sites each and included in this report were CG.3007, G.41, G.935, G.11, JM.1, JM.2, JM.7, PiAu 36-2, PiAu 51-11, PiAu 51-4, and PiAu 56-83.


The NC-140 Multi-State Research Committee has assisted tree-fruit growers with rootstock decisions for more than 35 years by evaluating performance of both old and new rootstocks in a range of climates and soils. The value of this support increases with the movement toward higher and higher density plantings, and the complexity of the decision increases with the release of more dwarfing, more precocious, higher yielding, more adaptable, and/or more pest-resistant rootstock clones.

Natural mutation occasionally results in rootstock strains which provide better performance than the original strain. Several strains of M.9 have been identified, and six have been evaluated previously in North America (Marini et al., 2006) with significant differences in vigor but similar yield efficiency. One strain of M.9 has not had significant evaluation in North America: M.9 Burgmer 756 (from Burgmer Nurseries in Germany). M.9 NAKB T337 (from the virus indexing program in the Netherlands) has had extensive testing and is the most commonly planted in North America. M.9 Nic 29 was tested in a multi-location trial from 1994-2003 and was found to be more vigorous than M.9 NAKB T337 (Marini et al., 2006). Testing that has been conducted in the U.S. (Perry and Byler, 2001) and Latvia (Rubauskis and Skrivele, 2007) suggests that M.9Burgmer

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756 performs similarly to M.9 NAKBT337, but M.9 Nic 29 may be better than M.9 Burgmer 756. After 5 years of the 2002 NC-140 Apple Rootstock Trial, there were some differences among the three M.9 strains: tree height (M.9 Burgmer 756 was taller), precocity and cumulative yield efficiency (M.9 Burgmer 756 had less flowering in the second year and lower yield efficiency), and root suckering (M.9 Nic 29 produced more than the others) (Autio et al., 2008).

The two strains of B.9 exhibit different growth habits in the nursery which has raised the concern that the strain of B.9 commonly used in Europe is different from the one used in North America (LoGiudice et al., 2006). The European strain of B.9 has a more trailing growth habit while the North American strain has a more erect growth habit (Russo et al., 2008). After five years of the 2002 NC-140 Apple Rootstock Trial, the North American strain of B.9 resulted in a larger trunk cross-sectional area than did the European strain, and the severity of burr knots was greater on the European strain than the North American strain (Autio et al., 2008).

Two strains of M.26 are available, M.26 NAKB (from the virus indexing program in the Netherlands) and M.26 EMLA (from the virus indexing program in Great Britain). After five years, no differences were measured in performance in the 2002 NC-140 Apple Rootstock Trial (Autio et al., 2008).

New rootstocks are also regularly available for testing, either after initial release or after their introduction to North America. P.14, an open-pollinated seedling of M.9, is from the Research Institute of Pomology, Skierniewice, Poland (Czynczyk and Jakubowski, 2007). Trials in Poland (Bielicki et al., 2009; Slowinski, 2004) suggested that trees on P.14 are somewhat larger than those on M.26 and comparably productive. In the 2002 NC-140 Apple Rootstock Trial, trees on P.14 were considerably larger and less efficient than those on either M.26 strain after five years (Autio et al., 2008).

Supporter 4 is from the Institut für Obstforschung Dresden-Pillnitz, Germany, and is reported to produce a tree similar to or slightly larger than those on M.26 but with greater yield efficiency (Fischer, 1997). In the 2002 NC-140 Apple Rootstock Trials after five years, trees on Supporter 4 were similar in size and productivity to those on the two M.26 strains (Autio et al., 2008). Fischer (2001) described the Pillnitz rootstocks PiAu 36-2, PiAu 51-11, PiAu 51-4 and PiAu 56-83. All were selected for resistance to apple scab and powdery mildew. None of them is resistant to fire blight (*Erwinia amylovora*) but they may be less susceptible than M.9. PiAu 51-4 and PiAu 51-11 are open-pollinated seedlings of M.4. PiAu 56-83 is an open-pollinated seedling of M.11, and the parentage of PiAu 36-2 is M.9 × (M.9 × *Malus baccata*). Fischer (2001) considered them semi-dwarfing, with yield efficiency comparable to, or better than, that of M.9.

The Cornell-Geneva Apple Rootstock Breeding Program of Cornell University and USDA has released several rootstocks both for testing and for commercial use, most being resistant to the fire blight bacterium. Robinson et al. (2011) reported that 'Honeycrisp' trees on CG.3007, G.11, and G.41 were slightly smaller and somewhat more yield efficient than those on M.9 in Geneva, NY, and similarly slightly more yield efficient and slightly larger than those on M.9 in Peru, NY. In the same study, 'Honeycrisp' trees on G.935 were slightly smaller and more yield efficient than those on M.9 in Geneva, NY, and slightly larger and similarly efficient to trees on M.26 in Peru, NY. G.11, G.41, and G.935 are all reported to be resistant to both fire blight and *Phytophthora* root rot (Robinson et al., 2011).

Three rootstocks from Japan were available for testing in limited supply: JM.1, JM.2 and JM.7. All three resulted from a cross of *M. prunifolia* × M.9, and were selected for ease of propagation by hardwood cuttings (Soejima et al., 1998). JM.1 is reportedly more dwarfing than M.9 EMLA, JM.7 similar to M.9 EMLA, and JM.2 is between M.9

EMLA and M.26 EMLA in dwarfing capacity. They showed fire blight resistance levels similar to M.7 in tests at Cornell University (Bessho et al., 2001). JM.1 and JM.7 tested as resistant to *Phytophthora cactorum* and moderately resistant to *P. cambivora* (agents causing crown rot), while JM.2 was resistant to *P. cambivora* but susceptible to *P. cactorum* (Soejima et al. 1998). JM.1 and JM.7 were also highly resistant to woolly apple aphid (Soejima et al., 1998).

The objectives of this trial were to assess and compare performance of P.14, Supporter 4, and different strains of B.9, M.26, and M.9. A further objective was to conduct a preliminary evaluation of four of the newest Cornell-Geneva rootstocks, three of the Japan-Morioka rootstocks, and four Pillnitz rootstocks from Germany using 'Buckeye Gala' as the scion cultivar.

## Materials and Methods

In spring, 2002, an orchard trial of apple rootstocks was established at six sites in North America and under the coordination of NC-140 Multi-State Research Committee. 'Buckeye Gala' was used as the scion cultivar, and rootstocks included B.9 North America (the strain commonly used in North America and propagated in stool beds at Treco Nursery, Woodburn, OR), B.9 Europe (the strain commonly used in Europe), M.26 EMLA, M.26 NAKB, M.9 Burgmer 756, M.9 Nic 29, M.9 NAKB T337, P.14, and Supporter 4. These rootstocks were tested at all six sites and form the core collection. Some sites also included CG.3007, Geneva® 11 (G.11), Geneva® 41 (G.41), and Geneva® 935 (G.935) (from the Cornell-Geneva Apple Rootstock Breeding Program, Geneva, New York, USA), JM.1, JM.2, and JM.7 (from the Apple Research Center in Morioka, Japan), and PiAu 36-2, PiAu 51-4, PiAu 51-11, and PiAu 56-83 (from the Institut für Obstforschung Dresden-Pillnitz, Germany).

The trial was planted in British Columbia (Canada), Chihuahua (Mexico), Kentucky, Massachusetts, New Jersey, and New York. Cooperators, their contact information, and specific locations for this trial are listed in

**Table 1.** Cooperating sites in the 2002 NC-140 Apple Rootstock Trial.

| Site | Planting location | Cooperator | Cooperator affiliation and address |
|---|---|---|---|
| British Columbia (BC) | Summerland | Cheryl Hampson | Pacific Agri-Food Res. Cntr, Agric. & Agri-Food Canada , P.O. Box 5000, Summerland, BC V0H1Z0 Canada |
| Chihuahua (CH) | Cuauhtémoc | Rafael Parra Quezada | Campo Exp. Sierra De Chihuahua, Av. Hildago No. 1213, Ap. Postal 554, CD. Cuauhtémoc, Chih., Mexico |
| Kentucky (KY) | Princeton | Dwight Wolfe | Research & Education Center, University of Kentucky, P.O. Box 469, Princeton, KY 42445 USA |
| | | Douglas Archbold | Dept. Horticulture, University of Kentucky, N-308C Agric. Science North, Lexington, KY 40546 USA |
| Massachusetts (MA) | Belchertown | Wesley Autio | Stockbridge School of Agriculture, Univ. Massachusetts, 205 Bowditch Hall, Amherst, MA 01003 USA |
| New Jersey (NJ) | Pittstown | Winfred Cowgill | Rutgers Cooperative Extension, PO Box 2900, Flemington, NJ 08822 USA |
| New York (NY) | Geneva | Terence Robinson | Dept. Horticultural Science, Cornell University, NYS Agric. Experiment Station, Geneva, NY 14456 USA |

Table 1. The experiment was arranged as a randomized complete block design at each location, with seven replications of a single tree on each rootstock. Trees were spaced 2.5 x 4.5 m and trained as vertical axes. Pest management, irrigation, and fertilization followed local recommendations at each site.

Trunk circumference, 25 cm above the bud union, was measured in October, 2011 and used to calculate trunk cross-sectional area (TCA). Also in October, 2011, tree height was measured, and canopy spread was assessed by averaging the in-row and across-row canopy widths. The severity of burr knots on the rootstock shank of each tree was determined by estimating the percent of the rootstock's circumference affected by burr knots. Root suckers were counted and removed each year.

Yield was assessed in 2004 through 2011. Yield efficiency ($kg \cdot cm^{-2}$ TCA) in 2011 and on a cumulative basis were calculated using 2011 TCA. Average fruit weight was assessed on a 50-apple sample (or available crop) each year.

Data were subjected to analysis of variance with the MIXED procedure of the SAS statistical analysis software (SAS Institute, Cary, NC). In the analysis, fixed main effects were rootstock and site. Block (within site) was a random, nested effect. In nearly all cases, the interaction of rootstock and site was significant. Rootstock differences within site were assessed (for all sites individually and including all rootstocks, also by the MIXED procedure) for mortality (through 2011), TCA (2011), cumulative yield (2004-11), cumulative yield efficiency (2004-11), and average fruit size (2004-11). All mean separation was by Tukey's HSD ($P = 0.05$).

## Results

*Core Rootstock Differences (averaged across sites).* Tree mortality was affected by rootstock (Table 2). The greatest mortality was for trees on Supporter 4 (35%), and the lowest was for trees on B.9 Europe (7%). Trees on other rootstocks experienced from 10 to 28% mortality. All P.14-rooted trees in CH died, so P.14 was removed from the core analysis but individual P.14 site effects are included in later tables.

Trees on M.9 Burgmer 756, Supporter 4, and M.26 NAKB had the highest TCA, significantly higher than M.9 NAKBT337, M.9 Nic 29, B.9 North America, and B.9 Europe (Table 2). Trees on the two B.9 strains were significantly smaller than trees on all other rootstocks. Tree height and canopy spread were more varied in response but followed

**Table 2.** Survival, trunk cross-sectional area, tree height, canopy spread, burr knot severity, and cumulative number of root suckers (2002-11) at the end of 2011 of 'Buckeye Gala' apple trees in the 2002 NC-140 Apple Rootstock Trial.[z]

| Rootstock | Survival (%) | Trunk cross-sectional area (2011, $cm^2$) | Tree height (2011, cm) | Canopy spread (2011, cm) | Burr knot severity (2011, % of trunk affected | Root suckers (2002-11, no./tree) |
|---|---|---|---|---|---|---|
| B.9 Europe | 93 a | 21.6 c | 264 c | 177 b | 4.5 ab | 28.9 b |
| B.9 North America | 78 ab | 30.5 c | 304 c | 219 b | 2.8 b | 12.8 c |
| M.26 EMLA | 72 ab | 57.5 ab | 344 b | 256 a | 6.7 ab | 2.7 c |
| M.26 NAKB | 90 ab | 66.7 a | 362 ab | 276 a | 8.5 a | 4.5 c |
| M.9 Burgmer 756 | 75 ab | 68.4 a | 394 a | 286 a | 2.2 b | 9.2 c |
| M.9 Nic 29 | 78 ab | 50.5 b | 345 b | 260 a | 1.9 b | 42.4 a |
| M.9 NAKBT337 | 73 ab | 55.0 b | 354 ab | 261 a | 3.2 ab | 14.9 c |
| Supporter 4 | 65 b | 67.3 a | 384 ab | 282 a | 3.1 ab | 10.2 c |

[z] Mean separation within column by Tukey's HSD ($P = 0.05$). All values are least-squares means adjusted for missing data.

similar trends as was seen with TCA (Table 2).

Burr knot severity was not high for any rootstock in the trial. Greatest severity was for M.26 NAKB, significantly more than for B.9 North America, M.9 Burgmer 756, and M.9 Nic 29. All other rootstocks had intermediate burr knot severity (Table 2).

M.9 Nic 29 produced significantly more root suckers than any other rootstock in the trial (Table 2). The second highest number of root suckers was produced by B.9 Europe, significantly more than all others (including B.9 North America), except for M.9 Nic 29.

Yield per tree in 2011 generally followed tree size, with the greatest yield from trees on M.9 Burgmer 756 and the lowest yields from trees on the two B.9 strains (Table 3). Cumulatively (2004-11), trees on M.9 Burgmer 756, M.26 NAKB, M.9 NAKBT337, and Supporter 4 yielded more than those on the B.9 strains. The most cumulatively yield efficient trees (2004-11) were on the two B.9 strains, and the least efficient were on M.26 EMLA and Supporter 4 (Table 3). Regarding strain differences, the two B.9 strains were similarly yield efficient, as were the two M.26 strains, and the three M.9 strains.

In 2011, M.9 Nic 29 resulted in larger fruit than did M.26 EMLA, and all other rootstocks resulted in intermediate fruit size (Table 3). On average over the 11-year fruiting life of the trial, the three M.9 strains and Supporter 4 resulted in larger fruit than did the two B.9 strains (Table 3). Interestingly, fruit from trees on B.9 North America were significantly larger than those on B.9 Europe when averaged over the 2004-11 period. The two M.26 strains resulted in fruit intermediate in size between the largest (M.9 strains and Supporter 4) and B.9 North America.

*Variation in Rootstock Performance by Site.* For all measurements rootstock and site interacted significantly to affect the results. Tables 4-8 show site-specific means.

Tree mortality differed significantly among rootstocks within sites (Table 4). Only modest losses were seen in MA, NJ, and NY, while much greater losses were seen in BC, CH, and KY. The two B.9 strains had greater than 50% survival at all sites. Trees on M.26 EMLA had poor survival in KY. In KY and CH, survival was poor for trees on M.9 Burgmer 756, M.9 NAKBT337, P.14, and Supporter 4. Among the additional rootstocks, trees on CG.3007 mostly died in CH but all survived in NY. Trees on JM.1 and JM.7 had poor survival in BC and 100% survival in NY. However, this latter difference may have been due to the fumigation of the trees with methyl bromide, required prior to importation to BC.

**Table 3.** Yield per tree in 2011 and cumulatively (2004-11), yield efficiency in 2011 and cumulatively (2004-11), and fruit weight in 2011 and on average (2004-11) of 'Buckeye Gala' apple trees in the 2002 NC-140 Apple Rootstock Trial.[z]

| | Yield per tree (kg) | | Yield efficiency (kg•cm$^{-2}$ TCA) | | Fruit weight (g) | |
|---|---|---|---|---|---|---|
| Rootstock | 2011 | Cumulative (2004-11) | 2011 | Cumulative (2004-11) | 2011 | Average (2004-11) |
| B.9 Europe | 11.1 c | 85 e | 0.47 a | 3.8 ab | 162 ab | 144 c |
| B.9 North America | 15.6 c | 121 d | 0.48 a | 3.9 a | 159 ab | 152 b |
| M.26 EMLA | 24.5 b | 154 c | 0.42 a | 2.7 d | 157 b | 157 ab |
| M.26 NAKB | 27.9 ab | 191 ab | 0.42 a | 2.9 cd | 164 ab | 158 ab |
| M.9 Burgmer 756 | 35.6 a | 214 a | 0.52 a | 3.0 cd | 170 ab | 163 a |
| M.9 Nic 29 | 31.3 ab | 168 bc | 0.54 a | 3.1 cd | 172 a | 160 a |
| M.9 NAKBT337 | 29.0 ab | 188 ab | 0.53 a | 3.3 bc | 167 ab | 162 a |
| Supporter 4 | 31.0 ab | 184 abc | 0.44 a | 2.7 d | 170 ab | 162 a |

[z] Mean separation within column by Tukey's HSD (P = 0.05). All values are least-squares means adjusted for missing data.

**Table 4.** Survival (%) by location at the end of the 2011 growing season of 'Buckeye Gala' apple trees on various rootstocks in the 2002 NC-140 Apple Rootstock Trial.[z]

| Rootstock | BC | CH | KY | MA | NJ | NY |
|---|---|---|---|---|---|---|
| B.9 Europe | 100 a | 86 a | 71 a | 100 a | 100 a | 100 a |
| B.9 North America | 71 ab | 57 ab | 71 a | 100 a | 71 a | 100 a |
| CG.3007 | --- | 17 ab | --- | --- | --- | 100 a |
| G.41 | --- | 57 ab | --- | --- | --- | 67 a |
| G.935 | --- | 80 ab | --- | --- | --- | 100 a |
| G.11 | --- | 60 ab | --- | --- | --- | --- |
| JM.1 | 0 b | --- | --- | --- | --- | 100 a |
| JM.2 | 67 ab | --- | --- | --- | --- | 100 a |
| JM.7 | 25 ab | --- | --- | --- | --- | 100 a |
| M.26 EMLA | 83 ab | 57 ab | 29 a | 83 a | 100 a | 83 a |
| M.26 NAKB | 100 a | 86 a | 57 a | 100 a | 100 a | 100 a |
| M.9 Burgmer 756 | 100 a | 43 ab | 14 a | 100 a | 100 a | 100 a |
| M.9 Nic 29 | 100 a | 57 ab | 57 a | 100 a | 71 a | 83 a |
| M.9 NAKBT337 | 86 ab | 43 ab | 43 a | 100 a | 100 a | 67 a |
| P.14 | 67 ab | 0 b | 43 a | 100 a | 100 a | 80 a |
| PiAu 36-2 | --- | --- | --- | --- | --- | 100 a |
| PiAu 51-11 | --- | --- | --- | 100 a | 83 a | 100 a |
| PiAu 51-4 | --- | --- | --- | 100 a | 100 a | 100 a |
| PiAu 56-83 | --- | --- | --- | --- | --- | 100 a |
| Supporter 4 | 50 ab | 14 ab | 43 a | 100 a | 100 a | 100 a |

[z] Mean separation within column by Tukey's HSD ($P = 0.05$). All values are least-squares means adjusted for missing data.

**Table 5.** Trunk cross-sectional area ($cm^2$) by location at the end of the 2011 growing season of 'Buckeye Gala' apple trees on various rootstocks in the 2002 NC-140 Apple Rootstock Trial.[z]

| Rootstock | BC | CH | KY | MA | NJ | NY |
|---|---|---|---|---|---|---|
| B.9 Europe | 29.1 d | 15.1 d | 14.6 c | 30.4 e | 19.0 f | 23.4 f |
| B.9 North America | 36.4 cd | 19.8 d | 27.7 c | 37.8 de | 29.4 ef | 33.7 f |
| CG.3007 | --- | 118.0 a | --- | --- | --- | 178.3 a |
| G.41 | --- | 42.5 b | --- | --- | --- | 45.1 ef |
| G.935 | --- | 44.2 b | --- | --- | --- | 54.8 def |
| G.11 | --- | 40.9 bc | --- | --- | --- | --- |
| JM.1 | --- | --- | --- | --- | --- | 70.2 cdef |
| JM.2 | 92.4 a | --- | --- | --- | --- | 127.1 abc |
| JM.7 | 48.8 bcd | --- | --- | --- | --- | 63.3 def |
| M.26 EMLA | 51.9 bc | 38.4 bcd | 60.4 bc | 75.6 c | 67.9 cd | 51.4 ef |
| M.26 NAKB | 45.3 bcd | 46.9 b | 82.8 b | 93.2 bc | 71.8 cd | 59.9 def |
| M.9 Burgmer 756 | 46.4 bcd | 37.4 bcd | 111.9 ab | 75.4 c | 71.0 cd | 68.0 def |
| M.9 Nic 29 | 43.1 cd | 21.9 cd | 57.3 bc | 61.3 cde | 53.5 de | 63.9 def |
| M.9 NAKBT337 | 37.4 cd | 19.6 d | 94.0 b | 64.1 cd | 61.0 d | 51.1 ef |
| P.14 | 79.2 a | --- | 161.2 a | 122.2 b | 104.9 ab | 100.7 bcd |
| PiAu 36-2 | --- | --- | --- | --- | --- | 120.0 abcd |
| PiAu 51-11 | --- | --- | --- | 112.9 b | 95.6 bc | 68.1 def |
| PiAu 51-4 | --- | --- | --- | 174.5 a | 132.0 a | 145.3 ab |
| PiAu 56-83 | --- | --- | --- | --- | --- | 133.7 ab |
| Supporter 4 | 70.4 ab | 38.9 bcd | 54.3 bc | 93.2 bc | 69.5 cd | 78.5 cde |

[z] Mean separation within column by Tukey s HSD ($P = 0.05$). All values are least-squares means adjusted for missing data.

Differences in trunk cross-sectional area among the core rootstocks were reasonably consistent from site to site (Table 5). Trees on P.14 were larger than others in the core group and likely would be classified as being semidwarf. Among the additional rootstocks, CG.3007 (CH, NY) produced a semidwarf tree; G.41 (CH, NY), G.935 (CH, NY), and G.11 (CH) produced dwarf trees in the larger end of the spectrum; JM.1 (NY) and JM.7 (BC, NY) produced large dwarf trees; and JM.2 (BC, NY) resulted in a semidwarf tree. PiAu 36-2 (NY), PiAu 51-11 (MA, NJ, NY), Pi 51-4 (MA, NJ, NY), and PiAu 56-83 (NY) all produced large trees ranging from semidwarf (PiAu 51-11) to semistandard (PiAu 51-4).

Cumulative (2004-11) yield per tree varied greatly from site to site (Table 6). Trees with the greatest yield were on JM.2 in both BC and NY, CG.3007 in CH, P.14 in both KY and NJ, and M.26 NAKB in MA.

The effects of rootstock on cumulative (2004-11) yield efficiency were relatively consistent from site to site, with trees on the B.9 strains being the most efficient, followed roughly by the M.9 strains and then the M.26 strains (Table 7). Trees on Supporter.4 were similar or somewhat lower than the M.26 strains, and those on P.14 were less yield efficient. Trees on JM.7 and JM.1 were similar to those on the M.9 strains. Trees on all of the PiAu rootstocks were among the least yield efficient.

Average (2004-11) fruit size was not dramatically affected by rootstock, and the effects were not greatly affected by site (Table 8). In BC and CH, the relative effects of rootstock on fruit size were nonsignificant. In KY, Supporter 4 and M.9 NAKBT337 resulted in larger fruit than did B.9 Europe. In MA and NJ, B.9 Europe resulted in the smallest fruit in the trial. In New York, M.9 Burgmer 756 and PiAu 51-4 resulted in larger fruit than did G.41.

**Table 6.** Cumulative yield per tree (kg, 2004-11) by location at the end of the 2011 growing season of 'Buckeye Gala' apple trees on various rootstocks in the 2002 NC-140 Apple Rootstock Trial.[z]

| Rootstock | BC | CH | KY | MA | NJ | NY |
|---|---|---|---|---|---|---|
| B.9 Europe | 145 c | 8 d | 46 c | 83 d | 84 d | 149 d |
| B.9 North America | 189 abc | 18 cd | 95 c | 104 cd | 118 cd | 203 cd |
| CG.3007 | --- | 95 a | --- | --- | --- | 352 ab |
| G.41 | --- | 43 bc | --- | --- | --- | 256 abcd |
| G.935 | --- | 37 bcd | --- | --- | --- | 328 abc |
| G.11 | --- | 39 bcd | --- | --- | --- | --- |
| JM.1 | --- | --- | --- | --- | --- | 272 abcd |
| JM.2 | 248 a | --- | --- | --- | --- | 406 a |
| JM.7 | 215 abc | --- | --- | --- | --- | 331 ab |
| M.26 EMLA | 182 bc | 37 bcd | 144 bc | 172 ab | 178 b | 210 bcd |
| M.26 NAKB | 187 abc | 44 b | 283 b | 214 a | 200 ab | 220 bcd |
| M.9 Burgmer 756 | 193 abc | 26 bcd | 420 ab | 166 ab | 191 ab | 273 abc |
| M.9 Nic 29 | 179 bc | 14 d | 212 bc | 156 abc | 170 bc | 273 abc |
| M.9 NAKBT337 | 183 bc | 14 d | 326 ab | 156 abc | 191 ab | 250 bcd |
| P.14 | 236 ab | --- | 508 a | 179 ab | 239 a | 338 ab |
| PiAu 36-2 | --- | --- | --- | --- | --- | 262 abcd |
| PiAu 51-11 | --- | --- | --- | 131 bcd | 182 b | 238 bcd |
| PiAu 51-4 | --- | --- | --- | 184 ab | 221 ab | 336 ab |
| PiAu 56-83 | --- | --- | --- | --- | --- | 331 ab |
| Supporter 4 | 228 ab | 42 bcd | 194 bc | 160 abc | 196 ab | 289 abc |

[z] Mean separation within column by Tukey s HSD (P = 0.05). All values are least-squares means adjusted for missing data.

**Table 7.** Cumulative yield efficiency (kg·cm$^{-2}$ TCA, 2004-11) by location at the end of the 2011 growing season of 'Buckeye Gala' apple trees on various rootstocks in the 2002 NC-140 Apple Rootstock Trial.[z]

| Rootstock | BC | CH | KY | MA | NJ | NY |
|---|---|---|---|---|---|---|
| B.9 Europe | 5.1 ab | 0.6 a | 3.3 a | 2.8 a | 4.4 a | 6.3 a |
| B.9 North America | 5.4 a | 0.9 a | 3.7 a | 2.9 a | 4.0 ab | 6.3 a |
| CG.3007 | --- | 0.8 a | --- | --- | --- | 2.0 c |
| G.41 | --- | 1.0 a | --- | --- | --- | 6.2 a |
| G.935 | --- | 0.8 a | --- | --- | --- | 5.3 ab |
| G.11 | --- | 1.0 a | --- | --- | --- | --- |
| JM.1 | --- | --- | --- | --- | --- | 4.1 bc |
| JM.2 | 2.6 c | --- | --- | --- | --- | 3.2 bc |
| JM.7 | 4.4 abc | --- | --- | --- | --- | 5.1 ab |
| M.26 EMLA | 3.7 c | 0.9 a | 2.4 a | 2.3 ab | 2.6 cd | 4.2 b |
| M.26 NAKB | 4.1 bc | 0.9 a | 3.4 a | 2.3 ab | 2.8 cd | 3.8 bc |
| M.9 Burgmer 756 | 4.3 bc | 0.7 a | 3.8 a | 2.3 ab | 2.8 cd | 4.3 b |
| M.9 Nic 29 | 4.2 bc | 0.7 a | 3.6 a | 2.6 a | 3.1 bc | 4.4 b |
| M.9 NAKBT337 | 5.0 ab | 0.7 a | 3.5 a | 2.5 ab | 3.1 bc | 5.0 ab |
| P.14 | 3.1 c | --- | 3.2 a | 1.4 c | 2.3 cde | 3.4 bc |
| PiAu 36-2 | --- | --- | --- | --- | --- | 2.2 c |
| PiAu 51-11 | --- | --- | --- | 1.3 c | 2.0 de | 3.5 bc |
| PiAu 51-4 | --- | --- | --- | 1.0 c | 1.7 e | 2.4 c |
| PiAu 56-83 | --- | --- | --- | --- | --- | 2.5 c |
| Supporter | 43.2 c | 1.1 a | 3.6 a | 1.7 bc | 2.9 cd | 3.8 bc |

[z] Mean separation within column by Tukey s HSD (P = 0.05). All values are least-squares means adjusted for missing data.

**Table 8.** Average fruit size (g, 2004-11) by location at the end of the 2011 growing season of 'Buckeye Gala' apple trees on various rootstocks in the 2002 NC-140 Apple Rootstock Trial.[z]

| Rootstock | BC | CH | KY | MA | NJ | NY |
|---|---|---|---|---|---|---|
| B.9 Europe | 184 a | 95 a | 143 b | 162 c | 156 b | 127 ab |
| B.9 North America | 184 a | 104 a | 160 ab | 172 bc | 167 ab | 129 ab |
| CG.3007 | --- | 122 a | --- | --- | --- | 133 ab |
| G.41 | --- | 121 a | --- | --- | --- | 119 b |
| G.935 | --- | 116 a | --- | --- | --- | 128 ab |
| G.11 | --- | 115 a | --- | --- | --- | --- |
| JM.1 | --- | --- | --- | --- | --- | 126 ab |
| JM.2 | 180 a | --- | --- | --- | --- | 137 ab |
| JM.7 | 186 a | --- | --- | --- | --- | 126 ab |
| M.26 EMLA | 183 a | 109 a | 169 ab | 185 ab | 167 ab | 130 ab |
| M.26 NAKB | 186 a | 108 a | 166 ab | 184 ab | 176 a | 130 ab |
| M.9 Burgmer 756 | 192 a | 103 a | 172 ab | 194 a | 174 a | 142 a |
| M.9 Nic 29 | 188 a | 109 a | 158 ab | 198 a | 170 ab | 135 ab |
| M.9 NAKBT337 | 190 a | 105 a | 176 a | 195 a | 167 ab | 134 ab |
| P.14 | 186 a | --- | 169 ab | 194 a | 178 a | 139 ab |
| PiAu 36-2 | --- | --- | --- | --- | --- | 141 ab |
| PiAu 51-11 | --- | --- | --- | 187 a | 180 a | 139 ab |
| PiAu 51-4 | --- | --- | --- | 187 a | 175 a | 144 a |
| PiAu 56-83 | --- | --- | --- | --- | --- | 139 ab |
| Supporter 4 | 184 a | 105 a | 177 a | 188 a | 179 a | 139 ab |

[z] Mean separation within column by Tukey s HSD (P = 0.05). All values are least-squares means adjusted for missing data.

## Discussion

*B.9 Strains*. This is the first trial to attempt to determine whether or not there are performance differences between B.9 used in North America and B.9 used in Europe. LoGiudice et al. (2006) were not able to find differences in DNA or susceptibility of the rootstock liner or grafted trees to fire blight bacteria; however, in the trial reported here some differences were beginning to develop. After 10 years, few significant differences existed between the two strains, although trees on the North American strain were numerically larger in TCA, height, and spread and had numerically fewer severe burr knots. The only significant differences were lower numbers of root suckers, higher cumulative yield and larger fruit size for the North American strain compared to the European strain.

*M.26 Strains*. After 10 years, no significant differences were evident between size of trees on M.26 EMLA and M.26 NAKB. Further, burr knot severity, root suckering, yield efficiency, and fruit size were statistically similar between the two strains. The only difference measured in this study was that trees on M.26 NAKB yielded more than did trees on M.26 EMLA on a cumulative basis.

*M.9 Strains*. Among the M.9 strains, tree size varied. M.9 Burgmer 756 produced trees with greater TCA than the other two strains. Also, trees on M.9 Burgmer 756 were taller than those on M.9 Nic 29. Root suckering was much higher from M.9 Nic 29 than the other two strains. Cumulative yield was higher for trees on M.9 Burgmer 756 than M.9 Nic 29, but yield efficiency and fruit size were similar among the three strains. Marini et al. (2006), in a large multi-location trial, found that tree size on M.9 Nic29 was larger than M.9 NAKBT337. Perry and Byler (2001) and Rubauskis and Skrivele (2007) found similar relationships in tree size among these three strains.

*Supporter 4*. In nearly all measures, trees on Supporter 4 were statistically similar to those on M.26 NAKB. Although the difference was not significant, it appeared that trees on Supporter 4 experienced somewhat greater mortality than did those on M.26 NAKB. Five-year results from another NC-140 trial (Autio et al., 2005) with ‘Fuji’ and ‘McIntosh’ on Supporter 4 and M.26 EMLA agree with the results reported here; however, Fischer (1997) reported that size of trees on Supporter 4 was similar to that of trees on M.26, but trees on Supporter 4 were more productive.

*P.14*. Because of complete tree death in CH, P.14 was dropped from the core analysis, but it was still present at five out of six sites. Tree size was larger than for the M.26 strains, likely in the semidwarf category. Yield efficiency of trees on P.14 tended to be low but was not generally significantly lower than for the M.26 strains. Czynczyk and Jakubowski (2007) and Slowinski (2004) found a similar size relationship to the one observed in this trial, and they found P.14 to have similarly cumulative yield efficient to M.26 (after ten years for Czynczyk and Jakubowski (2007) and five years for Slowinski (2004)).

Among the rootstocks with only limited planting, G.11, G.41, G.935, JM.1, and JM.7 resulted in reasonably small and yield efficient trees, the smallest and most efficient were those on G.41. JM.2 produced trees much larger than those on M.26 EMLA, with low to moderate yield efficiency. None of the un-named Pillnitz rootstocks performed well in this trial. All produced trees which were semidwarf or larger, and all trees had relatively low yield efficiency. Fischer (2001), however, reported that trees on PiAu 36-2 and on PiAu 51-4 were only 29% and 26% larger, respectively, than those on M.9, and that trees on PiAu 51-11 and PiAu 56-83 were 6% and 32% smaller, respectively, than those on M.9. Fischer (2001) also noted that trees on these four rootstocks were comparably efficient to trees on M.9: 6% less, 9% less, 11% more, and 22% more for PiAu 36-2, PiAu 51-4, PiAu 51-11, and PiAu 56-83, respectively.

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***About the Cover:***

Bins of freshly harvested sour oranges (also known as Seville or bitter oranges), at the JB Ranch in Seville, California (located between Woodlake and Ivanhoe), owned by Jim Boyles, CEO of Vita-Pakt Citrus Products, which uses the fruits for marmalade base, and sells some of them for fresh market. *(Photograph: David Karp)*