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

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Abstract

In 2002, an orchard trial of apple rootstocks was established at nine locations in Canada, Mexico, and the United States using 'Buckeye Gala' as the scion cultivar. Rootstocks included B.9 (North American or Treco 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 5 years, the greatest mortality was for trees on M.9 NAKBT337 (33%), and the lowest was for trees on M.26 NAKB (13%), B.9 Treco (13%), and B.9 Europe (10%). P.14 resulted in the largest trees based on trunk cross-sectional area. Smallest trees were on the two B.9 strains, with the European strain significantly smaller than the North American strain. Largest trees in the intermediate group were on Supporter 4, followed by those on M.26 NAKB, M.26 EMLA, M.9 Burgmer 756, M.9 Nic 29, and M.9 NAKBT337. Burr knot severity was highest on B.9 Europe and the two strains of M.26 compared to all other rootstocks. The severity of burr knots on the European strain of B.9 (20% of the circumference affected) was significantly greater than on the North American strain (7% of the circumference affected). Trees on M.26 NAKB, M.9 NAKBT337, and M.9 Nic 29 yielded more (cumulatively, 2004-06) than those on P.14 or B.9 Europe. The most yield efficient trees (cumulatively, 2004-06) were on the two B.9 strains, and the least efficient were on P.14. On average over the first 3 years of fruiting, M.9 Burgmer 756 resulted in larger fruit than did B.9 Europe or M.26 NAKB.

The selection of the most appropriate rootstock for new apple plantings has become increasingly complicated with the introduction of new rootstocks potentially with better yield performance, size control, and/or pest resistance and with the continual movement toward higher and higher planting densities. The NC-140 Multi-State Research Committee has assisted tree-fruit growers with this decision for more than 30 years by evaluating performance of both old and new rootstocks in a range of climates and soils.

In additional to the development of new rootstocks, new strains of older rootstocks become available from time to time. These strains arise from chance mutations in the field and those induced in tissue culture. Several strains of M.9 have been identified and 6 have been evaluated previously in North America (7) with significant differences in vigor but similar orchard productivity. One strain of M.9 has not had significant evaluation in North America: Burgmer 756 (from Burgmer Nurseries in Germany). NAKB T337 (from the virus indexing program in the Netherlands) has had extensive testing and is the most commonly planted in North America. Nic 29 was tested in a multi-location trial from 1994-2003 and was found to be more vigorous than NAKB T337 (7). Testing that has been conducted in the U.S. (8) and Latvia (9) suggests that Burgmer 756 performs similarly to NAKBT337, but Nic 29 may be better than Burgmer 756.

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 (6). The European strain of B.9 has a more trailing growth habit while the North American strain has a more erect growth habit (10).

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).

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 (3). Trials in Poland (2, 11) suggested that trees on P.14 are somewhat larger than those on M.26 and comparably productive. 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 (4).

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 some of the newest Cornell-Geneva rootstocks, three of the Japan-Morioka rootstocks, and four Pillnitz rootstocks from Germany.

Materials and Methods

In spring, 2002, an orchard trial of apple rootstocks was established under the coordination of NC-140 Multi-State Research Committee. 'Buckeye Gala' was used as the scion cultivar, and core rootstocks included B.9 Treco (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. 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).

Table 1. Cooperating sites in the 2002 NC-140 apple rootstock trial.

Site	Planting location	Cooperator	Cooperator affiliation and address
Arkansas	Fayetteville	Curt Rom	Dept. Horticulture, 316 Plant Sciences Building, University of Arkansas, Fayetteville, AR 72701 USA
British Columbia	Summerland	Cheryl Hampson	Pacific Agri-Food Res. Cntr, Agric. & Agri-Food Canada , P.O. Box 5000, Summerland, BC V0H1Z0 Canada
Chihuahua	Cuauhtémoc	Rafael Parra Quezada	Campo Exp. Sierra De Chihuahua, Av. Hildago No. 1213, Ap. Postal 554, CD. Cuauhtémoc, Chih., Mexico
Illinois	Urbana	Mosbah Kushad	Dept. Nat. Resources & Environmental Sci., 279 EMRL, 1201 West Gregory Drive, Urbana, IL 61801 USA
Kentucky	Princeton	Joseph Masabni	Research & Education Center, University of Kentucky, P.O. Box 469, Princeton, KY 42445 USA
Massachusetts	Belchertown	Wesley Autio	Dept. Plant, Soil, & Insect Sci., Univ. Massachusetts, 205 Bowditch Hall, Amherst, MA 01003 USA
Michigan	Clarkesville	Ronald Perry	Dept. Horticulture, Michigan State University, East Lansing, MI 48824 USA
New Jersey	Pittstown	Winfred Cowgill	Rutgers Cooperative Extension, PO Box 2900, Flemington, NJ 08822 USA
New York	Geneva	Terence Robinson	Dept. Horticultural Sciences, Cornell University, NYS Agric. Experiment Station, Geneva, NY 14456 USA

The trial was planted in Arkansas, British Columbia (Canada), Chihuahua (Mexico), Illinois, Kentucky, Massachusetts, Michigan, New Jersey, and New York. Arkansas, British Columbia, Kentucky, Massachusetts, Michigan, New Jersey, and New York are considered the core sites, since they include all of the core rootstocks (both B.9 strains, both M.26 strains, all three M.9 strains, P.14, and Supporter 4). Both Illinois and Chihuahua had complete mortality of trees on one of the core rootstocks. Cooperators, their contact information, and specific locations for this trial are listed in 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 4.5m 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, 2006 and used to calculate trunk cross-sectional area (TCA). Also in October, 2006, 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, 2005, and 2006. Yield efficiency (kg/cm^2 TCA) in 2006 and on a cumulative basis were calculated using 2006 TCA. Average fruit weight was assessed on a 50-apple sample (or available crop) each year.

Data from the core sites and rootstocks 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 2006), TCA (2006), cumulative yield (2004-06), cumulative yield efficiency (2004-06), and average fruit size (2004-06). All mean separation was by Tukey's HSD (P = 0.05).

Table 2. Mortality over the life of the planting, trunk cross-sectional area, tree height, canopy spread, and severity of burr knots in 2006, and cumulative number of root suckers of 'Gala' apple trees as part of the 2002 NC-140 apple rootstock trial.[z]

Rootstock	Tree mortality (%)[y]	Trunk cross-sectional area (cm^2)[x]	Tree height (m)[w]	Canopy Spread (m)[x]	Burr knot severity (%)[w]	Root suckers (no./tree, 2002-06)[x]
B.9 Europe	10 c	13.0 e	2.9 e	1.8 d	20 a	4.0 b
B.9 Treco	13 bc	17.6 d	3.1 d	2.2 c	7 b	1.9 bc
M.26 EMLA	31 ab	30.3 bc	3.5 c	2.4 b	20 a	0.7 c
M.26 NAKB	13 bc	31.2 b	3.5 c	2.5 b	18 a	0.7 c
M.9 Burgmer 756	24 abc	29.6 bc	3.9 b	2.5 b	2 b	2.5 bc
M.9 Nic 29	17 abc	27.9 bc	3.5 c	2.5 b	6 b	9.3 a
M.9 NAKBT337	33 a	25.2 c	3.5 c	2.5 b	3 b	3.9 bc
P.14	28 abc	43.4 a	4.3 a	2.8 a	5 b	0.6 c
Supporter 4	32 ab	32.4 b	3.7 bc	2.7 ab	5 b	2.4 bc

[z] Mean separation within column and cultivar by Tukey's HSD (P = 0.05). All values are least-squares means adjusted for missing data.
[y] Includes data from all locations.
[x] Includes data from Arkansas, British Columbia, Kentucky, Massachusetts, Michigan, New Jersey, and New York.
[w] Includes data from British Columbia, Kentucky, Massachusetts, Michigan, New Jersey, and New York.

Results

Core Rootstock Differences Across the Core Sites. Tree mortality was affected by rootstock (Table 2). The greatest mortality was for trees on M.9 NAKBT337 (33%), and the lowest was for trees on M.26 NAKB (13%), B.9 Treco (13%), and B.9 Europe (10%). Trees on Supporter 4, M.26 EMLA, and P.14 also experienced high mortality of approximately 30%.

P.14 had significantly greater TCA than any other rootstock (Table 2). Trees on the two B.9 strains were significantly smaller than trees on all other rootstocks. Trees on B.9 Europe were significantly smaller than those on B.9 Treco. Supporter 4 resulted in the largest trees of the intermediate group, followed by M.26 NAKB, M.26 EMLA, M.9 Burgmer 756, M.9 Nic 29, and M.9 NAKBT337, in descending TCA. Tree height and canopy spread followed similar trends (Table 2).

Burr knot severity on B.9 Europe and the two strains of M.26 was significantly higher than on all other rootstocks (Table 2). Interestingly, the severity of burr knots on the European strain of B.9 (20% of the circumference affected) was significantly greater than on the North American strain (7% of the circumference affected).

M.9 Nic 29 produced significantly more root suckers than any other rootstock in the trial (Table 2). The two strains of M.26 and P.14 produced the fewest root suckers. Other rootstocks produced intermediate numbers of root suckers.

Precocity was assessed through bloom counts at three locations in the second and third growing seasons (Table 3). B.9 Europe and M.9 NAKBT337 resulted in the greatest bloom density in the second season, followed by B.9 Treco and M.9 Nic 29 and the two M.26 strains. Among the M.9 strains, Burgmer 756 had significantly lower flower density in the second year than NAKBT337 while Nic29 was intermediate. Lowest flower density was noted on trees on P.14. There was no difference in flower density among rootstocks in the third growing season.

Yield per tree in 2006 was significantly greater from trees on Supporter 4 than from trees on the two B.9 strains (Table 3), with other rootstocks resulting in intermediate yields. Cumulatively (2004-06), trees on M.26 NAKB, M.9 NAKBT337, and M.9 Nic 29 yielded more than those on P.14 or B.9 Europe. The most yield efficient trees in 2006 and cumulatively (2004-06) were on the two B.9 strains, and the least efficient were on P.14 (Table 3). Among strains of M.9, NAKBT337 was more efficient than Burgmer 756 while Nic29 was intermediate. There was no difference in yield efficiency between strains of M.26. Yield efficiency was very closely associated with tree size. In fact, TCA accounted for almost all of the variance in cumulative yield efficiency (r^2=0.94, P<0.0001).

Fruit weight was not affected by rootstock in 2006 (Table 3). On average over the 3-year fruiting life of the trial, M.9 Burgmer 756 resulted in larger fruit than did B.9 Europe or M.26 NAKB. Other rootstocks resulted in intermediate fruit size.

Variation in Rootstock Performance by Site. For all measurements, except blossom density in 2003 and 2004, rootstock and site interacted significantly to affect the results. Tables 4-8 show site-specific means.

Tree mortality differed significantly among rootstocks within sites, with Illinois and Chihuahua losing 100% of trees on M.9 NAKBT337 and P.14, respectively (Table 4). Chihuahua, Arkansas, and Kentucky reported some tree losses on all rootstocks. Illinois and Michigan reported losses on all rootstocks, except P.14, B.9 Europe, and M.9 Nic 29. Only New Jersey did not experience tree losses on any rootstock, and Massachusetts reported a 17% loss only for trees on M.26 EMLA. Losses of trees on M.26 EMLA were reported in seven of the nine sites, while losses of trees on B.9 Europe were reported in only four of the nine sites (Table 4).

Among the core rootstocks, few dramatic differences existed in TCA among sites (Table 5). In general, tree size, in increasing order, went from B.9 to M.9 to M.26 to Supporter

Table 3. Bloom in 2003 and 2004, yield per tree in 2006 and cumulatively (2004-06), yield efficiency in 2006 and cumulatively (2004-06), and fruit weight in 2006 and on average (2004-06) of 'Gala' apple trees as part of the 2002 NC-140 apple rootstock trial.[z]

	Blossom density (no./ cm^2 TCA)		Yield per tree (kg)		Yield efficiency (kg/cm^2 TCA)		Fruit weight (g)	
Rootstock	2003[y]	2004[x]	2006[w]	Cumulative (2004-06)[w]	2006[w]	Cumulative (2004-06)[w]	2006[w,v]	Average (2004-06)[w]
B.9 Europe	13.7 a	16.2 a	11.6 c	28 d	0.87 a	2.1 a	177 a	151 c
B.9 Treco	10.1 ab	14.8 a	13.1 bc	34 bcd	0.76 ab	2.0 a	181 a	160 abc
M.26 EMLA	9.2 abc	14.3 a	15.0 abc	38 abc	0.50 cd	1.2 cd	186 a	161 abc
M.26 NAKB	9.1 abc	13.4 a	15.9 abc	42 a	0.53 cd	1.4 bc	181 a	156 bc
M.9 Burgmer 756	5.3 bc	15.3 a	15.4 abc	36 abc	0.53 cd	1.2 cd	185 a	170 a
M.9 Nic 29	9.6 ab	13.7 a	16.6 ab	40 ab	0.58 c	1.4 bc	184 a	164 ab
M.9 NAKBT337	13.3 a	15.4 a	17.6 ab	41 ab	0.69 bc	1.6 b	187 a	163 ab
P.14	2.1 c	13.0 a	17.7 ab	32 cd	0.40 d	0.8 e	178 a	163 a
Supporter 4	7.1 abc	18.5 a	17.9 a	37 abc	0.52 cd	1.1 de	184 a	166 ab

[z] Mean separation within column and cultivar by Tukey's HSD (P = 0.05). All values are least-squares means adjusted for missing data.
[y] Includes data from British Columbia, Kentucky, and New York.
[x] Includes data from British Columbia, New Jersey, and New York.
[w] Includes data from Arkansas, British Columbia, Kentucky, Massachusetts, Michigan, New Jersey, and New York.
[v] Least-squares means were adjusted for crop load within location.

Table 4. Mortality (%) of 'Gala' apple trees on various rootstocks as part of the 2002 NC-140 apple tootstock trial.[z]

Rootstock	AR	BC	KY	MA	MI	NJ	NY	Chih.	IL
B.9 Europe	50 a	0 b	14 a	0 a	0 b	0 a	0 a	14 b	14 b
B.9 Treco	43 a	0 b	14 a	0 a	14 b	0 a	0 a	29 ab	14 b
M.26 EMLA	29 a	0 b	43 a	17 a	57 ab	0 a	17 a	43 ab	71 a
M.26 NAKB	14 a	0 b	14 a	0 a	14 b	0 a	0 a	14 b	67 ab
M.9 Burgmer 756	43 a	0 b	71 a	0 a	14 b	0 a	0 a	43 ab	43 ab
M.9 Nic 29	29 a	0 b	14 a	0 a	0 b	0 a	17 a	43 ab	43 ab
M.9 NAKBT337	29 a	14 ab	43 a	0 a	71 a	0 a	0 a	43 ab	100 a
P.14	33 a	29 ab	29 a	0 a	43 ab	0 a	20 a	100 a	0 b
Supporter 4	57 a	33 ab	14 a	0 a	29 ab	0 a	0 a	85 ab	71 ab
CG.3007	---	---	---	---	---	---	0 a	81 ab	---
G.41	---	---	---	---	---	---	0 a	43 ab	---
G.935	---	---	---	---	---	---	34 a	19 b	---
G.11	---	---	---	---	---	---	---	57 ab	---
JM.1	---	75 a	---	---	---	---	0 a	---	---
JM.2	---	33 ab	---	---	---	---	0 a	---	---
JM.7	---	75 a	---	---	---	---	0 a	---	---
PiAu 36-2	---	---	---	---	---	---	0 a	---	---
PiAu 51-11	---	---	---	0 a	0 a	0 a	0 a	---	---
PiAu 51-4	---	---	---	0 a	39 ab	0 a	0 a	---	---
PiAu 56-83	---	---	---	---	---	---	0 a	---	---

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

4 to P.14. Although the differences in TCA were nonsignificant at each site, trees on B.9 Treco were larger than those on B.9 Europe at all sites.

Cumulative (2004-06) yield per tree varied greatly from site to site (Table 6). Differences among the core rootstocks were nonsignificant in Arkansas, British Columbia, and New York. Among the other six sites, trees on M.26 NAKB always were among the highest yielding, and at five of the six sites, trees on B.9 Europe were among the lowest yielding.

The effects of rootstock on cumulative (2004-06) yield efficiency were relatively consistent from site to site, with the B.9 strains being the most efficient and P.14 being the least efficient (Table 7). In Arkansas and Mexico, differences among the core rootstocks were nonsignificant. In Illinois, Supporter 4, M.9 Nic 29, and M.26 EMLA were among the most yield efficient trees, unlike most other sites.

Average (2004-06) fruit size of trees on the core rootstocks did not differ significantly at seven of the nine sites (Table 8). In British Columbia and Massachusetts, significant rootstock differences were measured. In British Columbia, M.9 Burgmer 756 resulted in larger fruit than did B.9 Treco or the two M.26 strains. In Massachusetts, M.9 Burgmer 756 and M.9 Nic 29 resulted in larger fruit than did the two M.26 strains, P.14, or Supporter 4.

Cornell-Geneva, Morioka, and Pillnitz Rootstocks. Also in Tables 4-8 are data from the additional Cornell-Geneva, Morioka, and Pillnitz rootstocks. After five seasons, mortality of the JM rootstocks in British Columbia was high (Table 4). Mortality of CG.3007 and G.11 was high in Chihuahua. G.11, G.41, and G.935 appear to be in the M.9-size category; whereas, CG.3007, the JM rootstocks, and the PiAu rootstocks appear to be in the M.26 or

Table 5. Trunk cross-sectional area (cm^2) by location at the end of the 2006 growing season of 'Gala' apple trees on various rootstocks as part of the 2002 NC-140 apple rootstock trial.[z]

Rootstock	AR	BC	KY	MA	MI	NJ	NY	Chih.	IL
B.9 Europe	9.9 a	16.5 d	9.6 c	13.5 f	18.0 e	11.8 e	12.6 d	8.6 e	10.0 c
B.9 Treco	14.7 a	18.9 d	16.3 bc	15.5 f	21.0 e	17.2 e	19.8 cd	13.9 bcde	16.5 bc
M.26 EMLA	20.0 a	23.4 cd	32.3 b	27.7 d	52.7 bcd	31.8 cd	25.0 cd	21.1 b	21.9 abc
M.26 NAKB	17.3 a	22.7 cd	38.5 b	33.1 c	43.9 cd	34.6 c	28.1 cd	21.0 b	32.0 a
M.9 Burgmer 756	16.6 a	22.3 cd	44.0 ab	27.5 d	37.9 cd	29.5 cd	30.7 bcd	15.7 bcde	22.8 ab
M.9 Nic 29	24.8 a	22.6 cd	28.7 bc	23.2 e	38.8 cd	27.0 cd	29.6 bcd	11.0 cde	25.7 ab
M.9 NAKBT337	18.7 a	18.2 d	34.9 b	23.3 e	29.7 de	26.1 d	23.6 cd	10.0 de	---
P.14	15.9 a	37.3 ab	63.4 a	37.7 b	62.0 ab	43.3 ab	41.4 bc	---	34.2 a
Supporter 4	20.7 a	32.5 bc	35.9 b	30.4 cd	41.6 cd	28.8 cd	36.3 bc	21.1 b	19.9 abc
CG.3007	---	---	---	---	---	---	66.9 a	48.2 a	---
G.41	---	---	---	---	---	---	19.5 cd	14.7 bcde	---
G.935	---	---	---	---	---	---	25.4 cd	19.5 bc	---
G.11	---	---	---	---	---	---	---	17.4 bcd	---
JM.1	---	---	---	---	---	---	36.8 bc	---	---
JM.2	---	47.2 a	---	---	---	---	52.5 ab	---	---
JM.7	---	29.1 bcd	---	---	---	---	33.6 bc	---	---
PiAu 36-2	---	---	---	---	---	---	45.1 ab	---	---
PiAu 51-11	---	---	---	30.3 cd	54.6 bc	35.5 bc	27.8 cd	---	---
PiAu 51-4	---	---	---	47.6 a	79.2 a	49.6 a	52.2 ab	---	---
PiAu 56-83	---	---	---	---	---	---	45.0 ab	---	---

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

larger category (Table 5). Trees on CG.3007 were the largest of the trial in New York and in Chihuahua.

Cumulative yield of trees on G.41 and G.935 was relatively high in New York and Chihuahua, and yield of trees on G.11 was also high in Chihuahua (Table 6). JM.2 and JM.7 resulted in high yields in British Columbia and New York. Yield of trees on all the PiAu rootstocks was low in New York, but that of trees on PiAu 51-4 was high in New Jersey and Michigan and moderate in Massachusetts. Yield of trees on PiAu 51-11 was moderate in Michigan and New Jersey but low in Massachusetts.

Trees on CG.3007 had the lowest cumulative (2004-06) yield efficiency in New York and Chihuahua (Table 7), and trees on G.11 had the highest yield efficiency in Chihuahua. Trees on G.935 and G.41 were intermediate in yield efficiency. Trees on the JM rootstocks had low-to-moderate yield efficiency in New York, and in British Columbia, those on JM.2 had low efficiency and trees on JM.7 had moderate-to-high yield efficiency.

Few interesting differences were noted for average fruit size among the Cornell-Geneva, Morioka, or Pillnitz rootstocks (Table 8).

Discussion

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. (6) were not able to find differences in DNA or susceptibility of the rootstock liner or grafted trees to the fireblight bacteria (*Erwinia amylovora* Burrill); however, in the trial reported here some differences are beginning to develop. The North American strain resulted in a larger TCA than the European strain after five growing seasons, and the severity of burr knots was

Table 6. Cumulative (2004-06) yield per tree (kg) by location of 'Gala' apple trees on various rootstocks as part of the 2002 NC-140 apple rootstock trial.[z]

Rootstock	AR	BC	KY	MA	MI	NJ	NY	Chih.	IL
B.9 Europe	18 a	38 b	26 b	17 a	61 bc	16 b	25 abc	7 c	33 b
B.9 Treco	24 a	44 ab	42 ab	17 a	63 bc	23 ab	25 abc	12 abc	39 ab
M.26 EMLA	31 a	41 ab	64 a	11 bc	75 abc	31 a	13 c	19 abc	63 ab
M.26 NAKB	21 a	44 ab	63 a	15 ab	101 a	34 a	18 c	21 ab	70 a
M.9 Burgmer 756	26 a	37 b	77 a	9 cd	60 bc	31 a	16 c	11 abc	48 ab
M.9 Nic 29	32 a	48 ab	59 a	11 bc	74 abc	33 a	25 abc	8 bc	67 a
M.9 NAKBT337	29 a	42 ab	69 a	7 de	93 ab	31 a	19 bc	7 c	---
P.14	17 a	42 ab	72 a	6 de	41 c	29 a	15 c	---	38 b
Supporter 4	23 a	50 ab	60 a	3 e	69 abc	29 a	20 bc	21 ab	60 ab
CG.3007	---	---	---	---	---	---	17 c	15 abc	---
G.41	---	---	---	---	---	---	26 abc	19 abc	---
G.935	---	---	---	---	---	---	54 a	25 a	---
G.11	---	---	---	---	---	---	---	25 a	---
JM.1	---	---	---	---	---	---	25 abc	---	---
JM.2	---	55 a	---	---	---	---	46 ab	---	---
JM.7	---	57 a	---	---	---	---	31 abc	---	---
PiAu 36-2	---	---	---	---	---	---	13 c	---	---
PiAu 51-11	---	---	---	5 e	52 bc	24 ab	12 c	---	---
PiAu 51-4	---	---	---	11 bc	72 abc	32 a	16 c	---	---
PiAu 56-83	---	---	---	---	---	---	11 c	---	---

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

greater on the European strain than the North American strain. Burr knot development has been associated with dogwood borer (*Synanthedon scitula* Harris) infestation in eastern U.S. orchards (5). It is uncertain how these differences will progress over the next 5 years of this trial.

At this point, no significant differences are evident between M.26 EMLA and M.26 NAKB. For the most part there were no significant differences among the three M.9 strains, with the exception of tree height (Burgmer 756 was taller), precocity and cumulative yield efficiency (Burgmer 756 had less flowering in the second year and lower yield efficiency) and root suckering (Nic 29 produced more than the others). There appears to be a general trend in tree size developing, with Burgmer 756 larger than Nic 29 and Nic 29 larger than NAKBT337. If these are true differences, they will continue to develop over the next 5 years of this trial. Marini et al., (7) in a large multi-location trial, found Nic29 was larger than NAKBT337. Perry and Byler (8) and Rubauskis and Skrivele (9) found similar relationships in size among these three strains.

Over the first 5 years of this trial, P.14 produced trees which were the largest in the trial with the lowest yield efficiency, significantly lower than either M.26 strain. This result is in contrast to that of Czynczyk and Jakubowski (3) and Slowinski (8) who found a similar size relationship to the one observed in this trial, but they found P.14 to have similarly cumulative yield efficient to M.26 [after 10 years for Cznczyk and Jakubowski (3) and 5 years for Slowinski (8)]. Again, the differences noted in this trial may change in the next 5 years.

After the first five seasons, trees in this trial on Supporter 4 were similar to those on M.26 in size and productivity but have fewer burr knots. Five-year results from another NC-140 trial (1) with 'Fuji' and 'McIntosh' on Supporter 4 and M.26 EMLA agree with

Table 7. Cumulative (2004-06) yield efficiency (kg/cm² TCA) by location of 'Gala' apple trees on various rootstocks as part of the 2002 NC-140 apple rootstock trial.[z]

Rootstock	AR	BC	KY	MA	MI	NJ	NY	Chih.	IL
B.9 Europe	1.8 a	2.4 a	2.7 a	1.2 a	3.6 a	1.3 a	2.0 a	0.8 bc	3.2 a
B.9 Treco	1.7 a	2.3 a	2.7 a	1.2 a	3.3 ab	1.3 a	1.3 abc	0.8 bc	2.3 ab
M.26 EMLA	1.5 a	1.9 abc	2.0 ab	0.4 bc	1.4 cd	1.0 ab	0.5 cd	0.9 abc	3.1 a
M.26 NAKB	1.3 a	2.0 ab	1.7 bc	0.5 b	2.4 abc	1.0 ab	0.7 bcd	1.0 abc	2.2 ab
M.9 Burgmer 756	1.6 a	1.7 bcd	1.8 abc	0.3 bcd	1.7 cd	1.1 ab	0.5 cd	0.7 c	2.2 ab
M.9 Nic 29	1.4 a	2.2 ab	2.0 ab	0.5 b	1.9 bcd	1.2 ab	0.8 bcd	0.7 c	2.8 a
M.9 NAKBT337	1.5 a	2.4 a	1.9 abc	0.3 bcd	3.2 abc	1.2 ab	0.8 bcd	0.7 c	---
P.14	1.3 a	1.2 cd	1.2 c	0.1 d	0.6 d	0.7 b	0.3 d	---	1.2 b
Supporter 4	1.1 a	1.6 bcd	1.8 abc	0.1 d	1.7 cd	1.0 ab	0.5 cd	1.0 abc	3.2 a
CG.3007	---	---	---	---	---	---	0.2 d	0.3 c	---
G.41	---	---	---	---	---	---	1.4 ab	1.3 ab	---
G.935	---	---	---	---	---	---	1.8 ab	1.3 ab	---
G.11	---	---	---	---	---	---	---	1.4 a	---
JM.1	---	---	---	---	---	---	0.7 bcd	---	---
JM.2	---	1.1 d	---	---	---	---	0.8 bcd	---	---
JM.7	---	2.0 ab	---	---	---	---	0.9 bcd	---	---
PiAu 36-2	---	---	---	---	---	---	0.3 d	---	---
PiAu 51-11	---	---	---	0.1 d	1.0 cd	0.7 b	0.4 d	---	---
PiAu 51-4	---	---	---	0.2 cd	0.9 cd	0.7 b	0.3 d	---	---
PiAu 56-83	---	---	---	---	---	---	0.2 d	---	---

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

the results reported here; however, Fischer (4) reported that size of trees on Supporter 4 was similar in size to those on M.26, but trees on Supporter 4 were more productive.

Several factors have contributed to tree mortality observed in this trial, with fireblight causing the most extensive damage in Illinois, Chihuahua, Michigan, and Arkansas. Some the sites attributed some losses due to wind breakage at the graft union, mice, and borers, and in British Columbia, losses may have resulted from fumigation treatment during quarantine.

Among the rootstocks with only limited planting, G.11, G.41, and G.935 have resulted in reasonably small and yield efficient trees. The smallest and most yield efficient of the trees on the Morioka rootstocks are on JM.7. None of the un-named Pillnitz rootstocks are performing well in this trial. Trees on PiAu 51-11 are similar in size to M.26, but they and trees on the other PiAu rootstocks have low yield efficiency.

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Table 8. Average (2004-06) weight (g) by location of fruit harvested from 'Gala' apple trees on various rootstocks as part of the 2002 NC-140 apple rootstock trial.[z]

Rootstock	AR	BC	KY	MA	MI	NJ	NY	Chih.	IL
B.9 Europe	111 a	194 ab	165 a	146 b	135 a	167 a	142 a	94 a	130 a
B.9 Treco	143 a	184 b	175 a	155 ab	139 a	170 a	153 a	105 a	130 a
M.26 EMLA	156 a	182 b	185 a	133 cd	147 a	173 a	152 a	111 a	132 a
M.26 NAKB	122 a	186 b	183 a	122 cd	152 a	176 a	153 a	114 a	153 a
M.9 Burgmer 756	145 a	200 a	199 a	158 a	155 a	170 a	162 a	98 a	139 a
M.9 Nic 29	146 a	195 ab	174 a	158 a	147 a	175 a	153 a	113 a	176 a
M.9 NAKBT337	134 a	195 ab	192 a	155 ab	146 a	163 a	157 a	98 a	---
P.14	129 a	188 ab	191 a	146 b	157 a	166 a	159 a	---	139 a
Supporter 4	162 a	193 ab	191 a	120 d	160 a	173 a	164 a	103 a	133 a
CG.3007	---	---	---	---	---	---	140 a	139 a	---
G.41	---	---	---	---	---	---	152 a	117 a	---
G.935	---	---	---	---	---	---	142 a	116 a	---
G.11	---	---	---	---	---	---	---	119 a	---
JM.1	---	---	---	---	---	---	160 a	---	---
JM.2	---	189 ab	---	---	---	---	155 a	---	---
JM.7	---	183 b	---	---	---	---	154 a	---	---
PiAu 36-2	---	---	---	---	---	---	168 a	---	---
PiAu 51-11	---	---	---	135 c	144 a	170 a	152 a	---	---
PiAu 51-4	---	---	---	155 ab	140 a	172 a	152 a	---	---
PiAu 56-83	---	---	---	---	---	---	147 a	---	---

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

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