# Early Performance of 'Fuji' and 'McIntosh' Apple Trees on Several Dwarf Rootstocks in the 1999 NC-140 Rootstock Trial

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**Keywords**

*Malus x domestica*, yield efficiency, tree size, fruit size, Cornell-Geneva rootstocks, Pillnitz rootstocks

**Abstract**

'Fuji' and 'McIntosh' apple trees (*Malus x domestica* Borkh.) on CG.3041, CG.4013, CG.5179, CG.5202, G.16N (liners from stool beds), G.16T (liners from tissue cultured plants), M.9 NAKBT337, M.26 EMLA, Supporter 1, Supporter 2, and Supporter 3 rootstocks were planted at 19 locations ('Fuji' at 10 sites and 'McIntosh' at 10 sites) throughout North America as a uniform trial coordinated by the NC-140 Technical Committee. After five growing seasons, the only significant loss was of trees on M.9 NAKBT337, where only 67% remained. The largest trees were on CG.4013, and the smallest 'Fuji' trees were on Supporter 1, Supporter 2, Supporter 3, and M.9 NAKBT337. Trees on CG.4013 yielded the most over the first 3 years of fruiting. Trees on M.9 NAKBT337 and M.26 EMLA had among the lowest yields over this period. Trees on most other rootstocks yielded similarly and consistently between the two cultivars. Trees on Supporter 1, Supporter 2, Supporter 3, G.16N, G.16T, and M.9 NAKBT337 consistently were the most yield efficient (cumulatively). Those on M.26 EMLA, CG.5202, and CG.4013 were consistently the least efficient. M.26 EMLA, M.9 NAKBT337, and CG.5202 consistently resulted in average fruit weight within the highest group. Supporter 1, Supporter 2, and Supporter 3 resulted in among the smallest fruit. G.16N and G.16T resulted in the largest 'Fuji' fruit and among the smallest 'McIntosh' fruit.

## INTRODUCTION

The rootstock is a critical component of any orchard management system. Modern, high-density systems, particularly, require careful selection of rootstock to assure success and ultimately adequate return on a relatively high investment. The NC-140 Technical Committee began in 1976 with the goal of evaluating rootstocks over a wide variety of North American conditions in uniform trials. Initial studies focused on East Malling, Michigan, Budagovsky, and Polish rootstocks (NC-140, 1991, 1996). Many other rootstocks have been released since that time. The Cornell-Geneva Apple Rootstock Breeding Program (a cooperative effort between Cornell University and the United States Department of Agriculture) has begun to release rootstocks in a wide variety of dwarfing categories, all reported to be highly productive and disease resistant (Johnson et al., 2001a). Likewise, the Institut für Obstforschung Dresden-Pillnitz has released a number of dwarfing rootstocks, reported to be similar in size to trees on M.9 and more productive (Fischer, 2001).

The objective of the 1999 NC-140 Apple Rootstock Trial was to evaluate Cornell-Geneva and Pillnitz rootstocks in comparison to M.9 NAKBT337 and M.26 EMLA, utilizing several locations and uniform plantings.

## MATERIALS AND METHODS

In spring, 1999, two trials of dwarf apple rootstocks were established under the coordination of the NC-140 Technical Committee. One trial included 'Fuji' apple trees on CG.4013, CG.5179, CG.5202, G.16N (liners from stool beds), G.16T (liners from tissue cultured plants), M.9 NAKBT337, M.26 EMLA, Supporter 1, Supporter 2, and Supporter 3 and was planted in California, Kentucky, Missouri, North Carolina, Ohio, Pennsylvania (Biglerville), and Utah (Table 1). Partial plantings were initiated in Pennsylvania (Rock Springs), South Carolina, and Washington, and some sites included CG.3041 and CG.5935. A second trial included 'McIntosh' apple trees on CG.3041, CG.4013, CG.5179, CG.5202, G.16N, G.16T, M.9 NAKBT337, M.26 EMLA, Supporter 1, Supporter 2, and Supporter 3 and was planted in Massachusetts, Michigan, Minnesota, Nova Scotia (Canada), New York (Geneva), Vermont, and Wisconsin (Table 2). Partial plantings were established in New York (Champlain), Ontario (Canada), and Pennsylvania (Rock Springs), and some sites included CG.5935.

Trees were spaced 3x5m and trained as vertical axes. Water, fertility, and pest control were per local recommendations. The experimental design was a randomized complete block at each site, with six blocks and a single tree representing each rootstock treatment in a block. Trunk circumference at 25cm above the bud union was measured annually in October and transformed to trunk cross-sectional area (TCA). Tree height was measured in October, 2003. Canopy spread was assessed in October, 2003 as the average of the in-row and across-row canopy widths. Root suckers were counted and removed annually in August. Yield per tree was assessed in 2001 through 2003 as total weight of the harvested and dropped fruit. Fruit size was derived from the total weight of harvested fruit divided by the total number of harvested fruit per tree.

Data were analyzed with the MIXED procedure of the SAS statistical analysis software (SAS Institute, Cary, NC, USA). The two trials ('Fuji' and 'McIntosh') were analyzed separately and each treated as a randomized-complete-block-split-plot design, with location as the whole plot and rootstock as the split plot. Least-squares means, adjusted for missing subclasses, were generated by the analyses. Rootstock means were separated by Tukey's HSD ($P = 0.05$).

## RESULTS AND DISCUSSION

After five growing seasons, the only significant loss was of trees on M.9 NAKBT337, where only 74% and 67% of 'Fuji' and 'McIntosh' trees, respectively, remained. The largest 'Fuji' trees and the largest 'McIntosh' trees were on CG.4013 (Tables 3 and 4). The smallest 'Fuji' trees were on Supporter 1 and Supporter 2, and the smallest 'McIntosh' were on M.9 NAKBT337 and Supporter 1.

Root suckering was much more prominent with 'Fuji' as the scion cultivar compared to 'McIntosh' (Tables 3 and 4). CG.4013 and CG.5202 resulted in more than twice the root suckering than did M.9 NAKBT337.

Rootstock effects on cumulative yield per tree (2001-03) varied somewhat between 'Fuji' (Table 3) and 'McIntosh' (Table 4). Generally, however, trees on CG.4013 yielded the most over the first 3 years of fruiting. Trees on M.9 NAKBT337 and M.26 EMLA had among the lowest yields over this period. Trees on most other rootstocks yielded similarly and consistently between the two cultivars. Trees on CG.5202, however, were among the lowest yielding 'Fuji' trees and the highest yielding 'McIntosh' trees.

Trees on Supporter 1, Supporter 2, Supporter 3, G.16N, G.16T, and M.9 NAKBT337

consistently were the most yield efficient (cumulatively, 2001-03) (Tables 3 and 4). Those on M.26 EMLA, CG.5202, and CG.4013 were consistently the least efficient. 'McIntosh' trees on CG.5179 were in the highest category of efficiency. 'Fuji' trees on CG.5179, on the other hand, were not in the highest category but were not significantly different than M.9 NACBT337 in yield efficiency. CG.3041 (planted in this trial only with 'McIntosh' as the scion) were among the most yield efficient.

Effects of rootstock on fruit weight were modest (Tables 3 and 4). M.26 EMLA and M.9 NAKBT337 resulted in average fruit weight (2001-03) within the highest group. CG.5202, likewise, resulted in among the largest 'Fuji' and 'McIntosh' fruit. The three Supporter rootstocks resulted in among the smallest fruit. G.16N and G.16T resulted in the largest 'Fuji' fruit and among the smallest 'McIntosh' fruit. 'McIntosh' fruit from trees on CG.3041 were within the largest category.

The results presented here must be labeled preliminary, since they are based only on the first five growing seasons, but they give an early look at some of the newest and potentially useful dwarf apple rootstocks from the Cornell-Geneva Rootstock Breeding Program (Johnson et al., 2001a) and the Pillnitz Rootstock Breeding Program (Fischer, 2001). These data place these new rootstocks into four distinct size categories. Trees on CG.4013 were semidwarfs, larger than those on M.26 EMLA. Trees on CG.5202 were large dwarfs, similar in size to M.26 EMLA. Trees on CG.5179, CG.3041, G.16N, and G.16T were moderate dwarfs, between trees on M.26 EMLA and M.9 NAKBT337 and likely similar to the larger M.9 clones. Trees on Supporter 1, Supporter 2, and Supporter 3 were small dwarfs, similar in size to trees on M.9 NAKBT337. Regarding yield efficiency, for the semidwarf tree-size category, CG.4013 resulted in high yielding trees that were similarly efficient or somewhat more yield efficient than those on M.26 EMLA. In the large dwarf category, trees on CG.5202 were similarly yield efficient to those on M.26 EMLA. Within the moderate dwarf category, trees on G.16N, G.16T, CG.3041, and CG.5179 were similarly yield efficient. Within the small dwarf category, Supporter 1, Supporter 2, and Supporter 3 were highly yield efficient but not significantly different from trees on M.9 NAKBT337. Robinson et al. (2002, 2004a, 2004b) placed the G and CG stocks in similar categories to those reported here. Likewise, Fischer (1997, 2001) categorized the Supporter stocks consistent with the results of this trial.

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**Literature Cited**

Fischer, M. 1997. The Pillnitz apple rootstock breeding methods and selection results. Acta Hort. 451:89-97.

Fischer, M. 2001. New dwarfing and semidwarfing Pillnitz apple and pear rootstocks. Acta Hort. 557:55-61.

Johnson, W.C., H.S. Aldwinckle, J.N. Cummins, P.L. Forsline, H.T. Holleran, J.L. Norelli, and T.L. Robinson. 2001a. The new USDA-ARS/Cornell University Apple Rootstock Breeding and Evaluation Program. Acta Hort. 557:35-40.

Johnson, W.C., J.N. Cummins, H.T. Holleran, S.A. Hoying, and T.L. Robinson. 2001b. Orchard trial performance of elite Geneva series rootstocks. Acta Hort. 557:63-67.

NC-140. 1991. Performance of ‘Starkspur Supreme Delicious’ apple on 9 rootstocks over 10 years in the NC-140 Cooperative Planting. Fruit Varieties J. 45:192-199.

NC-140. 1996. Performance of the NC-140 Cooperative Apple Rootstock Planting: I. Survival, tree size, yield and fruit size. Fruit Varieties J. 50:6-11.

Robinson, T., L. Anderson, W. Autio, A. Azarenko, B. Barritt, G. Brown, J. Cline, R. Crassweller, P. Domoto, C. Embree, A. Fennell, D. Ferree, E. Garcia, A. Gaus, G. Greene, C. Hampson, P. Hirst, E. Hoover, S. Johnson, M. Kushad, R. Marini, R. Moran, C. Mullins, M. Parker, R. Perry, J.P. Privé, G. Reighard, C. Rom, T. Roper, J. Schupp, and M. Warmund. 2002. Performance of Cornell-Geneva rootstocks in the North American NC-140 rootstock trials. Compact Fruit Tree 35:99-102.

Robinson, T., L. Anderson, A. Azarenko, B. Barritt, T. Baugher, G. Brown, R. Crassweller, P. Domoto, C. Embree, A. Fennell, E. Garcia, A. Gaus, R. Granger, G. Greene, P. Hirst, E. Hoover, S. Johnson, M. Kushad, R. Moran, C. Mullins, S. Myers, R. Perry, C. Rom, J. Schupp, M. Warmund, and J. Warner. 2004a. Performance of Cornell-Geneva rootstocks with ‘Liberty’ as the scion in NC-140 trials across North America. Acta Hort. (In press).

Robinson, T., L. Anderson, W. Autio, A. Azarenko, B. Barritt, G. Brown, J. Cline, R. Crassweller, P. Domoto, C. Embree, A. Fennell, D. Ferree, E. Garcia, A. Gaus, G. Greene, C. Hampson, P. Hirst, E. Hoover, S. Johnson, M. Kushad, R. Marini, R. Moran, C. Mullins, M. Parker, R. Perry, J.P. Privé, G. Reighard, C. Rom, T. Roper, J. Schupp, and M. Warmund. 2004b. Performance of Cornell-Geneva rootstock across North America in multi-location NC-140 rootstock trials. Acta Hort. (In press).

Table 1. Planting locations in the 1999 NC-140 Semidwarf Rootstock Trial – 'Fuji'.

| Site | Planting location | Cooperator | Cooperator Affiliation & Address |
|---|---|---|---|
| California | Parlier | S. Johnson | Kearney Agric. Center, University of California<br>9240 S. Riverbend Ave., Parlier, CA 93648 USA |
| Kentucky | Princeton | J. Masabni | Research & Education Center, University of Kentucky<br>P.O. Box 469, Princeton, KY 42445 USA |
| Missouri | New Franklin | M. Warmund | Dept. Horticulture, University of Missouri<br>I-40 Agriculture Building, Columbia, MO 65211 USA |
| North Carolina | Fletcher | M. Parker | Dept. Horticulture, North Carolina State University<br>Box 7609, Raleigh, NC 27695 USA |
| Ohio | Wooster | D. Ferree | Dept. Hort. & Crop Science, Ohio State University<br>OARDC, Wooster, OH 44691 USA |
| Pennsylvania | Biglerville | G. Greene | Fruit Research & Ext. Cntr., Pennsylvania State Univ.<br>P.O. Box 330, Biglerville, PA 17307 USA |
| South Carolina | Seneca | G. Reighard | Dept. Horticulture, Clemson University<br>Box 340375, Clemson, SC 29634 USA |
| Utah | Logan | S.D. Seeley | Plant Science Dept., Utah State University<br>Logan, UT 84321 USA |
| Washington | Wenatchee | B. Barritt | Tree Fruit Res. & Ext. Cntr., Washington State Univ.<br>1100 N. Western Ave., Wenatchee, WA 98801 USA |

Table 2. Planting locations in the 1999 NC-140 Semidwarf Rootstock Trial – 'McIntosh'.

| Site | Planting location | Cooperator | Cooperator Affiliation & Address |
|---|---|---|---|
| Massachusetts | Belchertown | W. Autio | Dept. Plant, Soil, & Insect Sci., Univ. Massachusetts<br>205 Bowditch Hall, Amherst, MA 01003 USA |
| Michigan | Clarksville | R. Perry | Dept. Horticulture, Michigan State University<br>East Lansing, MI 48824 USA |
| Minnesota | Excelsior | E. Hoover | Dept. Horticultural Sci., University of Minnesota<br>1970 Folwell Ave, St. Paul, MN 55108 USA |
| Nova Scotia (Canada) | Kentville | C. Embree | Agriculture & Agri-Food Canada<br>Kentville, NS B4N 1J5 Canada |
| New York | Williamson | T. Robinson | Dept. Horticultural Science, Cornell University<br>NYS Agric. Experiment Station, Geneva, NY 14456 USA |
| New York | Peru | T. Robinson | Dept. Horticultural Science, Cornell University<br>NYS Agric. Experiment Station, Geneva, NY 14456 USA |
| Ontario (Canada) | Simcoe | J. Cline | Dept. Plant Agriculture, University of Guelph<br>Box 587, Simcoe, ONT N3Y 4N5 Canada |
| Pennsylvania | Rock Springs | R. Crassweller | Dept. Horticulture, Pennsylvania State University<br>102 Tyson Building, University Park, PA 16802 USA |
| Vermont | South Burlington | M.E. Garcia | Dept. Plant & Soil Science, University of Vermont<br>206 Hills Building, Burlington, VT 05405 |
| Wisconsin | Sturgeon Bay | K. Kosola | Dept. Horticulture, University of Wisconsin<br>1575 Linden Drive, Madison, WI 53706 USA |

Table 3. Survival, tree size, number of root suckers, yield, and fruit size of 'Fuji' apple trees on various rootstocks through the first five growing seasons (1999-2003) as part of the 1999 NC-140 Dwarf Rootstock Trial. All values are least-squares means adjusted for missing subclasses and are derived only from California, Kentucky, Missouri, North Carolina, Ohio, Pennsylvania (Biglerville), and Utah locations.[1]

| Rootstock | Survival (%) | Trunk cross-sectional area ($cm^2$) | Tree height (m) | Canopy spread (m) | Cumulative no. root suckers per tree (1999-2003) | Cumulative yield per tree (kg) (2001-03) | Cumulative yield efficiency ($kg/cm^2$ TCA) (2001-03) | Average fruit weight (g) (2001-03) |
|---|---|---|---|---|---|---|---|---|
| CG.4013 | 100 a | 66.2 a | 3.6 a | 3.3 a | 13.8 a | 45 a | 0.78 cde | 188 abc |
| CG.5179 | 93 a | 35.4 cd | 3.3 ab | 3.0 ab | 7.2 bc | 32 bcd | 0.92 bcde | 191 ab |
| CG.5202 | 89 ab | 44.0 b | 3.5 a | 3.0 ab | 12.6 ab | 24 d | 0.63 e | 188 abc |
| G.16N[2] | 88 ab | 37.3 bcd | 3.0 bc | 2.7 cd | 1.9 c | 36 bc | 1.08 abc | 199 a |
| G.16T[2] | 83 ab | 39.9 bc | 3.1 b | 2.8 bc | 2.5 c | 39 ab | 1.11 ab | 194 a |
| M.9 NAKBT337 | 74 b | 30.2 de | 3.0 bc | 2.6 cde | 5.4 bc | 28 cd | 1.01 abcd | 191 ab |
| M.26 EMLA | 86 ab | 44.2 b | 3.3 ab | 2.8 bc | 1.4 c | 24 d | 0.70 de | 189 abc |
| Supporter 1 | 88 ab | 22.3 f | 2.5 d | 2.2 f | 5.5 bc | 28 cd | 1.24 ab | 172 c |
| Supporter 2 | 95 a | 25.4 ef | 2.6 d | 2.4 ef | 1.8 c | 29 cd | 1.15 ab | 175 c |
| Supporter 3 | 94 a | 29.1 e | 2.8 cd | 2.5 de | 2.9 c | 34 bc | 1.25 a | 179 bc |

[1] Mean separation within columns by Tukey's HSD ($P = 0.05$).

[2] G.16N liners were from stool beds, and G.16T liners were tissue cultured plants.

Table 4. Survival, tree size, number of root suckers, yield, and fruit size of 'McIntosh' apple trees on various rootstocks through the first five growing seasons (1999-2003) as part of the 1999 NC-140 Dwarf Rootstock Trial. All values are least-squares means adjusted for missing subclasses and are derived only from Massachusetts, Michigan, Minnesota, Nova Scotia (Canada), New York (Geneva), Vermont, and Wisconsin locations.[1]

| Rootstock | Survival (%) | Trunk cross-sectional area ($cm^2$) | Tree height (m) | Canopy spread (m) | Cumulative no. root suckers per tree (1999-2003) | Cumulative yield per tree (kg) (2001-03) | Cumulative yield efficiency ($kg/cm^2$ TCA) (2001-03) | Average fruit weight (g) (2001-03) |
|---|---|---|---|---|---|---|---|---|
| CG.3041 | 100 a | 20.1 bcde | 3.2 cd | 3.0 abc | 0.5 b | 41 bcd | 2.09 a | 157 ab |
| CG.4013 | 100 a | 34.4 a | 3.8 a | 3.2 a | 2.4 a | 56 a | 1.69 b | 153 b |
| CG.5179 | 100 a | 22.2 bc | 3.5 abc | 3.1 ab | 0.5 b | 42 bc | 1.87 a | 152 b |
| CG.5202 | 95 a | 32.4 a | 3.8 a | 3.0 ab | 0.4 b | 44 b | 1.41 bc | 155 ab |
| G.16N[2] | 100 a | 20.5 bcde | 3.0 d | 2.6 c | 0.2 b | 39 bcde | 1.89 a | 150 b |
| G.16T[2] | 100 a | 20.8 bcd | 3.0 d | 2.6 c | 1.0 ab | 38 bcde | 1.82 a | 149 b |
| M.9 NAKBT337 | 67 b | 15.7 e | 3.3 bcd | 2.7 bc | 0.6 ab | 28 e | 1.76 ab | 160 ab |
| M.26 EMLA | 100 a | 24.0 b | 3.6 ab | 2.9 abc | 0.3 b | 33 de | 1.27 c | 162 a |
| Supporter 1 | 86 a | 17.8 de | 3.1 cd | 2.6 c | 1.8 ab | 35 cde | 1.95 a | 152 b |
| Supporter 2 | 88 a | 19.6 cde | 3.2 cd | 2.7 bc | 0.2 b | 38 bcde | 1.87 a | 149 b |
| Supporter 3 | 90 a | 20.1 cde | 3.1 cd | 2.7 bc | 0.5 b | 39 bcde | 1.93 a | 150 b |

[1] Mean separation within columns by Tukey's HSD ($P = 0.05$).

[2] G.16N liners were from stool beds, and G.16T liners were tissue cultured plants.