Journal of the American Pomological Society 59(4):202-214 2005

Performance of 'Fuji' and 'McIntosh' Apple Trees After 5 Years as Affected by Several Dwarf Rootstocks in the 1999 NC-140 Apple Rootstock Trial

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Abstract

'Fuji' and 'McIntosh' apple trees (*Malus x domestica* Borkh.) 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 rootstocks were planted at seven sites per cultivar throughout North America as a uniform trial coordinated by the NC-140 Technical Committee. Partial plantings were established at three sites per cultivar. CG.3041 and CG.5935 were included in eight and four sites per cultivar, respectively. After five growing seasons, trees on M.9 NAKBT337 showed the greatest loss, with 33% mortality. Tree size measurements of trunk cross-sectional area, tree height, and canopy spread were all affected by rootstock and were used to allocate each rootstock into four preliminary size categories. Trees on CG.4013 were semidwarfs, larger than those on M.26 EMLA. Trees on CG.5202 and CG.5935 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. 'Fuji' trees on CG.4013 were similarly yield efficient to trees on M.26 EMLA; however, comparable 'McIntosh' trees were significantly more efficient than those on M.26 EMLA. Trees on CG.5202 and CG.5935 were similarly yield efficient to those on M.26 EMLA, and trees on G.16N, G.16T, CG.3041, and CG.5179 were similarly yield efficient to those on M.9 NAKBT337. In the small dwarf category, trees on Supporter 1, Supporter 2, and Supporter 3 were similarly yield efficient to those on M.9 NAKBT337. Average fruit weight was only modestly affected by rootstock, and the rootstock influence was not consistent between the two cultivars.

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 (5, 6). 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 (3). 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 (2).

The objective of the portion of the 1999 NC-140 Apple Rootstock Trial reported here was to evaluate Cornell-Geneva and Pillnitz rootstocks in comparison to M.9 NA-

[1]The authors wish to acknowledge the International Dwarf Fruit Tree Association for the significant support provided for the establishment and coordination of this trial. Massachusetts Agricultural Experiment Station Paper 3350.

KBT337 and M.26 EMLA, utilizing several locations and uniform plantings.

Materials & 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' as the scion cultivar, and the other included 'McIntosh'. Core rootstocks were 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. Plantings at some sites also included CG.3041 and CG.5935 as rootstock treatments. The 'Fuji' trial was planted in California, Kentucky, Missouri, North Carolina, Ohio, Pennsylvania (Biglerville), and Utah, with partial plantings in Pennsylvania (Rock Springs), South Carolina, and Washington (Table 1). The 'McIntosh' trial was planted in Massachusetts, Michigan, Minnesota, Nova Scotia, New York (Williamson), Vermont, and Wisconsin, with partial plantings in New York (Peru), Ontario, and Pennsylvania (Rock Springs) (Table 1).

Trees were spaced 3x5m and trained as vertical axes. Water, fertility, and pest control were applied 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. Yield efficiency in 2003 was calculated as yield in 2003 divided by TCA in 2003. Cumulative yield efficiency (2001-03) was calculated as cumulative yield (2001-03) divided by TCA in 2003. Fruit size in 2003 was derived from the total weight of fruit harvested per tree in 2003 divided by the total number of harvested fruit per tree. Average fruit weight (2001-03) was calculated as the cumulative yield (2001-03) divided by the cumulative number of fruit.

Data were analyzed with the MIXED procedure of the SAS statistical analysis software (SAS Institute, Cary, NC). The two trials ('Fuji' and 'McIntosh') were analyzed separately. Data from the core rootstocks and sites were analyzed as a randomized-complete-block-split-plot design, with location (L) and block within location (B:L) in the whole plot and rootstock (R) and the associated interactions (RL and RB:L) in the split plot. Rootstock and location were treated as fixed effects, and block was considered random. In general, the interaction of location and rootstock was significant. Additional analyses, therefore, were conducted for each site, including all of the rootstocks at that site. Least-squares means, adjusted for missing subclasses, were generated by the analyses. Rootstock means were separated by Tukey's HSD ($P = 0.05$).

Results

Rootstock Effects Across the Core Sites

For the first five growing seasons, survival was significantly lower for trees on M.9 NAKBT337 than for respective 'Fuji' trees on CG.4013, CG.5179, Supporter 2, and Supporter 3 and 'McIntosh' trees on all of the other rootstocks (Table 2). Only 74% and 67% of 'Fuji' and 'McIntosh' trees, respectively, on M.9 NAKBT337 remained after 5 years.

'Fuji' and 'McIntosh' trees with the greatest

Table 1. Planting locations in the 1999 NC-140 Dwarf Rootstock Trial.

Site	Planting location	Cooperator	Cooperator Affiliation & Address
			'Fuji'
California	Parlier	S. Johnson	Kearney Agric. Center, University of California, 9240 S. Riverbend Ave., Parlier, CA 93648 USA
Kentucky	Princeton	J. Masabni	Research & Education Center, University of Kentucky, P.O. Box 469, Princeton, KY 42445 USA
Missouri	New Franklin	M. Warmund	Dept. Horticulture, University of Missouri, I-87 Agriculture Building, Columbia, MO 65211 USA
North Carolina	Fletcher	M. Parker	Dept. Horticulture, North Carolina State University, Box 7609, Raleigh, NC 27695 USA
Ohio	Wooster	D. Ferree	Dept. Hort. & Crop Science, Ohio State University, OARDC, Wooster, OH 44691 USA
Pennsylvania	Biglerville	G. Greene	Fruit Research & Ext. Cntr., Pennsylvania State Univ., P.O. Box 330, Biglerville, PA 17307 USA
Pennsylvania	Rock Springs	R. Crassweller	Dept. Horticulture, Pennsylvania State University, 102 Tyson Building, University Park, PA 16802 USA
South Carolina	Clemson	G. Reighard	Dept. Horticulture, Clemson University, Box 340319, Clemson, SC 29634 USA
Utah	Logan	S.D. Seeley	Plant Science Dept., Utah State University, Logan, UT 84321 USA
Washington	Wenatchee	B. Barritt	Tree Fruit Res. & Ext. Cntr., Washington State Univ., 1100 N. Western Ave., Wenatchee, WA 98801 USA
			'McIntosh'
Massachusetts	Belchertown	W. Autio	Dept. Plant, Soil, & Insect Sci., Univ. Massachusetts, 205 Bowditch Hall, Amherst, MA 01003 USA
Michigan	Clarksville	R. Perry	Dept. Horticulture, Michigan State University, East Lansing, MI 48824 USA
Minnesota	Excelsior	E. Hoover	Dept. Horticultural Sci., University of Minnesota, 1970 Folwell Ave, St. Paul, MN 55108 USA
Nova Scotia	Kentville	C. Embree	Agriculture & Agri-Food Canada, Kentville, NS B4N 1J5 Canada
New York	Williamson	T. Robinson	Dept. Horticultural Science, Cornell University, NYS Agric. Experiment Station, Geneva, NY 14456 USA
New York	Peru	T. Robinson	Dept. Horticultural Science, Cornell University, NYS Agric. Experiment Station, Geneva, NY 14456 USA
Ontario	Simcoe	J. Cline	Dept. Plant Agriculture, University of Guelph, Box 587, Simcoe, ONT N3Y 4N5 Canada
Pennsylvania	Rock Springs	R. Crassweller	Dept. Horticulture, Pennsylvania State University, 102 Tyson Building, University Park, PA 16802 USA
Vermont	South Burlington	M.E. Garcia	Dept. Plant & Soil Science, University of Vermont, 206 Hills Building, Burlington, VT 05405
Wisconsin	Sturgeon Bay	K. Kosola	Dept. Horticulture, University of Wisconsin, 1575 Linden Drive, Madison, WI 53706 USA

TCA were on CG.4013, CG.5202, and M.26 EMLA (Table 2). The smallest were on Supporter 1, Supporter 2, Supporter 3, and M.9 NAKBT337. The tallest 'Fuji' trees were on CG.4013, CG.5202, CG.5179, and M.26 EMLA, and the shortest were on Supporter 1, Supporter 2, and Supporter 3 (Table 2). The tallest 'McIntosh' trees were on CG.4013, CG.5202, M.26 EMLA, and CG.5179, and the shortest were on G.16N, G.16T, Supporter 1, Supporter 3, Supporter 2, and M.9 NAKBT337 (Table 2). CG.4013, CG.5179, and CG.5202 resulted in the largest 'Fuji' canopy spread, and Supporter 1, Supporter 2, and Supporter 3 resulted in the smallest (Table 2). CG.4013, CG.5179, CG.5202, and M.26 EMLA resulted in the largest 'McIntosh' canopy spread, and G.16N, G.16T, and Supporter 1 resulted in the smallest (Table 2).

Root suckering was much more prominent with 'Fuji' as the scion cultivar compared to 'McIntosh' (Table 2). CG.4013 resulted in the greatest number of root suckers with both cultivars, and CG.5202 resulted in substantial root suckering with 'Fuji'.

The greatest yields of both cultivars came from trees on CG.4013 in 2003 and cumulatively (Table 2). Lowest 'Fuji' yields were from trees on CG.5202 and M.26 EMLA in 2003 and cumulatively. The lowest 'McIntosh' yields in 2003 were from trees on M.9 NAKBT337 and those on Supporter 1. Cumulatively, the lowest 'McIntosh' yields were harvested from trees on M.9 NAKBT337 and M.26 EMLA.

'Fuji' trees on Supporter 1, Supporter 2, and Supporter 3 were the most yield efficient in 2003 and cumulatively (Table 2). Those on M.26 EMLA, CG.5202, and CG.4013 were the least efficient. 'McIntosh' trees on Supporter 1, Supporter 2, and M.9 NAKBT337 were the most yield efficient in 2003, and those on Supporter 1, Supporter 2, Supporter 3, G.16 N, G.16T, and CG.5179 were cumulatively the most yield efficient (Table 2). Those on M.26 EMLA and CG.5202 were the least yield efficient in 2003 and cumulatively.

Effects of rootstock on fruit weight were modest (Table 2), with no rootstock effect on 'McIntosh' weight in 2003. For 'Fuji', CG.4013, G.16T, and M.9 NAKBT337 resulted in larger fruit than did Supporter 1 in 2003. G.16T, G.16N, CG.5179, M.9 NAKBT337, M.26 EMLA, CG.4013, and CG.5202 resulted in average (2001-03) 'Fuji' fruit weight within the highest group. M.26 EMLA, M.9 NAKBT337, and CG.5202 resulted in the largest average (2001-03) 'McIntosh' fruit weight. The three Supporter rootstocks resulted in the smallest 'Fuji' fruit, and CG.4013, CG.5179, Supporter 1, Supporter 3, G.16N, Supporter 2, and G.16T resulted in the smallest 'McIntosh' fruit.

Interaction of Rootstock and Site

Most loss occurred of trees on M.9 NAKBT337, however, it was significantly greater than for other rootstocks at just a few sites (Table 3). For 'Fuji', greater loss of trees on M.9 NAKBT337 occurred primarily in MO, OH, and UT, and for 'McIntosh', greater loss occurred primarily in MN, NY(Williamson), and WI. In other locations, loss of trees on M.9 NAKBT337 was not significantly different from 100% survival. Across all rootstocks, the poorest survival (about 50%) was recorded in MO, where severe winds resulted in tree breakage.

Although the interaction of site and rootstock was statistically significant, the relative differences in TCA among rootstocks did not vary greatly from site to site (Table 4).

The relative differences among the effect of rootstock on cumulative yield varied somewhat from site to site (Table 5); however, trees on CG.4013 were consistently in the highest category, and those on M.26 EMLA and M.9 NAKBT337 were consistently in the lowest category.

Rootstock and site interacted significantly to affect cumulative yield efficiency, but a

Table 2. Survival, tree size, yield, and fruit size of 'Fuji' and '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. 'Fuji' data were derived only from California, Kentucky, Missouri, North Carolina, Ohio, Pennsylvania (Biglerville), and Utah locations. 'McIntosh' data were derived only from Massachusetts, Michigan, Minnesota, Nova Scotia, New York (Williamson), Vermont, and Wisconsin locations.[1]

Rootstock	Survival (%)	Trunk cross-sectional area (cm^2)	Tree height (m)	Canopy spread (m)	Cumulative no. root suckers (1999-2003)	Yield per tree (kg)		Yield efficiency (kg/cm^2 TCA)		Fruit weight (g)	
						2003	Cumulative (2001-03)	2003	Cumulative (2001-03)	2003[2]	Average (2001-03)
						'Fuji'					
CG.4013	100 a	66.2 a	3.6 a	3.3 a	13.8 a	19.4 a	45 a	0.35 bc	0.78 cde	207 a	188 abc
CG.5179	93 a	35.4 cd	3.3 ab	3.0 ab	7.2 bc	13.6 abcd	32 bcd	0.41 abc	0.92 bcde	204 ab	191 ab
CG.5202	89 ab	44.0 b	3.5 a	3.0 ab	12.6 ab	8.4 d	24 d	0.24 c	0.63 e	204 ab	188 abc
G.16N[3]	88 ab	37.3 bcd	3.0 bc	2.7 cd	1.9 c	17.3 abc	36 bc	0.53 ab	1.08 abc	200 ab	199 a
G.16T[3]	83 ab	39.9 bc	3.1 b	2.8 bc	2.5 c	18.3 ab	39 ab	0.52 ab	1.11 ab	206 a	194 a
M.9 NAKBT337	74 b	30.2 de	3.0 bc	2.6 cde	5.4 bc	11.0 bcd	28 cd	0.44 abc	1.01 abcd	207 a	191 ab
M.26 EMLA	86 ab	44.2 b	3.3 ab	2.8 bc	1.4 c	9.8 cd	24 d	0.30 bc	0.70 de	199 ab	189 abc
Supporter 1	88 ab	22.3 f	2.5 d	2.2 f	5.5 bc	13.3 abcd	28 cd	0.60 a	1.24 ab	187 b	172 c
Supporter 2	95 a	25.4 ef	2.6 d	2.4 ef	1.8 c	12.8 abcd	29 cd	0.52 ab	1.15 ab	190 ab	175 c
Supporter 3	94 a	29.1 e	2.8 cd	2.5 de	2.9 c	15.4 abcd	34 bc	0.60 a	1.25 a	195 ab	179 bc

Table 2 continued

Rootstock	Survival (%)	Trunk cross-sectional area (cm^2)	Tree height (m)	Canopy spread (m)	Cumulative no. root suckers (1999-2003)	Yield per tree (kg)		Yield efficiency (kg/cm^2 TCA)		Fruit weight (g)	
						2003	Cumulative (2001-03)	2003	Cumulative (2001-03)	2003[2]	Average (2001-03)
						'McIntosh'					
CG.4013	100 a	34.4 a	3.8 a	3.2 a	2.4 a	35.6 a	56 a	1.02 abcd	1.69 ab	146 a	153 b
CG.5179	100 a	22.2 bc	3.5 a	3.1 a	0.5 bc	27.4 bc	42 bc	1.15 ab	1.87 a	151 a	152 b
CG.5202	95 a	32.4 a	3.8 a	3.0 a	0.4 bc	30.7 ab	44 b	0.93 cd	1.41 bc	148 a	155 ab
G.16N[3]	100 a	20.5 bcd	3.0 b	2.6 b	0.2 c	23.1 cd	39 bcd	1.09 abc	1.89 a	148 a	150 b
G.16T[3]	100 a	20.8 bc	3.0 b	2.6 b	1.0 abc	22.1 cd	38 bcd	0.99 bcd	1.82 a	144 a	149 b
M.9 NAKBT337	67 b	15.7 d	3.3 b	2.7 ab	0.6 abc	20.9 d	28 d	1.18 a	1.76 ab	155 a	160 ab
M.26 EMLA	100 a	24.0 b	3.6 a	2.9 a	0.3 c	23.6 cd	33 d	0.83 d	1.27 c	148 a	162 a
Supporter 1	86 a	17.8 d	3.1 b	2.6 b	1.8 ab	21.5 d	35 cd	1.19 a	1.95 a	151 a	152 b
Supporter 2	88 a	19.6 cd	3.2 b	2.7 ab	0.2 c	23.9 cd	38 bcd	1.17 a	1.87 a	148 a	149 b
Supporter 3	90 a	20.1 cd	3.1 b	2.7 ab	0.5 bc	23.7 cd	39 bcd	1.13 abc	1.93 a	150 a	150 b

[1] Mean separation within column and cultivar by Tukey's HSD (P = 0.05).

[2] Fruit weight in 2003 was affected by crop load, and therefore least-squares means were adjusted to account for crop load.

[3] G.16N was originally propagated from stool beds, and G.16T originally came from tissue cultured plants.

Table 3. Survival (%) of 'Fuji' and 'McIntosh' apple trees by location 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.[1]

Rootstock	CA	KY	MO	NC	OH	PA-B	UT	PA-R	SC	WA
					'Fuji'					
CG.4013	100 a	100 a	100 a	100 a	100 a	100 a	100 a	-	-	100 a
CG.5179	100 a	83 a	83 ab	100 a	83 a	100 a	100 a	-	100 a	100 a
CG.5202	100 a	80 a	40 ab	100 a	100 a	100 a	100 a	-	-	-
G.16N [2]	100 a	100 a	40 ab	79 a	99 a	100 a	100 a	-	80 a	83 a
G.16T [2]	100 a	100 a	33 ab	83 a	100 a	100 a	67 ab	-	-	83 a
M.9 NAKBT337	100 a	100 a	17 b	100 a	50 a	100 a	50 b	100 a	100 a	81 a
M.26 EMLA	100 a	100 a	33 ab	83 a	83 a	100 a	100 a	100 a	-	100 a
Supporter 1	83 a	100 a	50 ab	100 a	83 a	100 a	100 a	100 a	100 a	100 a
Supporter 2	100 a	100 a	67 ab	100 a	100 a	100 a	100 a	100 a	80 a	83 a
Supporter 3	100 a	100 a	60 ab	99 a	100 a	100 a	100 a	100 a	100 a	100 a
CG.3041	100 a	48 a	24 ab	99 a	100 a	100 a	100 a	-	-	-
CG.5935	100 a	-	-	98 a	100 a	-	-	-	-	98 a
	MA	MI	MN	NS	NY-W	VT	WI	NY-P	ON	PA-R
					'McIntosh'					
CG.4013	100 a	100 a	100 a	100 a	100 a	100 a	100 a	-	83 a	-
CG.5179	100 a	100 a	100 a	100 a	100 a	100 a	100 a	-	100 a	-
CG.5202	100 a	83 a	100 a	100 a	100 a	80 a	100 a	-	97 a	-
G.16N [2]	100 a	100 a	100 a	100 a	100 a	100 a	100 a	-	79 a	-
G.16T [2]	100 a	100 a	100 a	100 a	100 a	100 a	100 a	-	97 a	-
M.9 NAKBT337	100 a	100 a	17 b	83 a	50 b	100 a	17 b	100 a	100 a	100 a
M.26 EMLA	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	-	100 a
Supporter 1	100 a	100 a	50 ab	100 a	100 a	100 a	50 ab	100 a	100 a	100 a
Supporter 2	100 a	100 a	67 a	100 a	100 a	100 a	50 ab	100 a	100 a	100 a
Supporter 3	100 a	100 a	83 a	83 a	83 a	100 a	83 a	100 a	83 a	83 a
CG.3041	100 a	100 a	100 a	100 a	100 a	100 a	100 a	-	99 a	-
CG.5935	-	100 a	100 a	-	100 a	100 a	-	-	-	-

[1] Mean separation within column and cultivar by Tukey's HSD (P = 0.05).

[2] G.16N was originally propagated from stool beds, and G.16T originally came from tissue cultured plants.

Table 4. Trunk cross-sectional area (cm^2) of 'Fuji' and 'McIntosh' apple trees by location 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.[1]

Rootstock	CA	KY	MO	NC	OH	PA-B	UT	PA-R	SC	WA
					'Fuji'					
CG.4013	118.2 a	53.4 a	77.2 a	57.6 a	57.2 a	36.4 a	63.7 a	-	-	19.6 abc
CG.5179	37.6 d	29.8 bc	45.7 b	38.9 bc	34.1 bc	26.0 b	36.0 bc	-	39.9 bc	20.1 abc
CG.5202	76.1 bc	36.9 b	47.8 b	41.3 bc	38.5 bc	24.9 b	43.2 b	-	-	-
G.16N [2]	66.3 c	36.1 b	52.2 ab	34.1 bcd	23.9 cd	22.1 bc	27.6 c	-	90.6 a	23.1 ab
G.16T [2]	74.8 bc	37.4 b	40.7 b	33.8 cd	33.2 bc	26.1 ab	33.8 bc	-	-	20.3 abc
M.9 NAKBT337	58.0 cd	28.9 bc	27.2 b	22.6 de	29.5 bcd	16.0 bc	30.0 bc	30.2 b	59.9 b	12.2 c
M.26 EMLA	97.0 ab	29.8 bc	38.5 b	47.2 ab	31.7 bc	25.8 b	40.0 bc	45.7 a	-	15.2 abc
Supporter 1	29.1 d	22.4 c	26.2 b	18.4 e	12.0 d	14.7 c	33.3 bc	19.5 cd	38.8 bc	13.9 bc
Supporter 2	39.7 d	28.7 bc	27.3 b	20.0 e	12.0 d	16.0 bc	34.1 bc	18.1 d	45.8 bc	11.4 c
Supporter 3	51.5 d	22.3 c	33.0 b	21.9 de	15.4 d	20.5 bc	39.5 bc	26.4 bc	36.4 c	14.4 bc
CG.3041	51.8 d	29.7 bc	28.1 b	24.1 de	32.9 bc	20.4 bc	36.0 bc	-	-	-
CG.5935	61.0 c	-	-	44.7 abc	45.0 ab	-	-	-	-	25.6 a
	MA	MI	MN	NS	NY-W	VT	WI	NY-P	ON	PA-R
					'McIntosh'					
CG.4013	29.9 a	58.7 a	32.1 a	26.0 a	52.7 a	24.4 ab	16.9 ab	-	43.6 a	-
CG.5179	21.9 bc	33.2 bcd	23.5 ab	14.1 bc	27.7 c	20.1 bcd	14.9 ab	-	37.6 ab	-
CG.5202	25.2 ab	57.7 a	31.0 ab	22.5 ab	40.5 ab	31.1 a	19.6 a	-	45.8 a	-
G.16N [2]	13.3 d	31.8 cd	20.0 b	22.2 ab	22.8 c	19.3 bcd	14.1 ab	-	28.6 bc	-
G.16T [2]	14.6 d	35.9 bcd	19.8 b	15.4 bc	25.8 c	20.6 bcd	14.3 ab	-	26.7 bc	-
M.9 NAKBT337	9.2 d	33.8 bcd	13.8 b	9.5 c	20.1 c	11.8 d	9.4 b	10.9 b	26.7 bc	24.6 b
M.26 EMLA	16.5 cd	44.9 b	17.6 b	18.4 abc	34.0 bc	21.7 abc	13.9 ab	19.2 a	-	43.5 a
Supporter 1	11.8 d	27.9 d	16.0 b	16.4 bc	27.5 c	14.1 cd	11.3 b	19.5 a	25.7 bc	29.5 b
Supporter 2	15.3 d	29.7 d	19.9 b	16.8 bc	29.0 bc	15.2 cd	12.0 b	15.6 ab	22.9 c	26.5 b
Supporter 3	16.3 d	25.8 d	18.7 b	19.0 abc	29.0 bc	16.0 bcd	15.9 ab	19.5 a	24.9 c	33.5 ab
CG.3041	16.4 cd	27.7 d	25.6 ab	14.7 bc	26.4 c	15.2 cd	15.9 ab	-	33.4 abc	-
CG.5935	-	42.5 bc	31.2 ab	-	42.7 ab	24.5 ab	-	-	-	-

[1] Mean separation within column and cultivar by Tukey's HSD (P = 0.05).

[2] G.16N was originally propagated from stool beds, and G.16T originally came from tissue cultured plants.

Table 5. Cumulative (2001-03) yield (kg) per tree of 'Fuji' and 'McIntosh' apple trees by location 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.[1]

Rootstock	CA	KY	MO	NC	OH	PA-B	UT	PA-R	SC	WA
					'Fuji'					
CG.4013	23 abc	75 a	53 a	37 ab	5 a	49 a	70 a	-	-	13 ab
CG.5179	31 a	39 ab	48 a	34 ab	2 ab	32 ab	42 bc	-	82 a	14 ab
CG.5202	23 abc	44 ab	30 a	21 abc	2 ab	30 ab	28 c	-	-	-
G.16N [2]	25 abc	68 ab	50 a	30 abc	1 ab	36 ab	51 abc	-	88 a	24 a
G.16T [2]	30 ab	65 ab	50 a	37 ab	2 ab	50 a	55 abc	-	-	23 a
M.9 NAKBT337	27 abc	38 ab	47 a	15 c	1 ab	25 b	56 abc	34 b	73 a	12 ab
M.26 EMLA	18 c	30 b	29 a	20 abc	2 ab	42 ab	41 bc	31 b	-	10 b
Supporter 1	17 c	58 ab	39 a	13 c	1 ab	33 ab	49 abc	40 b	57 a	16 ab
Supporter 2	20 bc	52 ab	46 a	15 c	0 b	34 ab	50 abc	35 b	65 a	16 ab
Supporter 3	17 c	63 ab	56 a	16 bc	0 b	39 ab	57 ab	60 a	60 a	21 ab
CG.3041	18 c	72 ab	42 a	30 abc	3 ab	37 ab	41 bc	-	-	-
CG.5935	33 a	-	-	44 a	5 a	-	-	-	-	19 ab
	MA	MI	MN	NS	NY-W	VT	WI	NY-P	ON	PA-R
					'McIntosh'					
CG.4013	66 a	92 ab	36 a	59 a	66 ab	46 ab	27 ab	-	41 a	-
CG.5179	49 ab	71 abc	28 ab	26 bc	51 b	41 abc	27 ab	-	36 a	-
CG.5202	49 ab	83 abc	33 ab	36 bc	42 b	42 abc	28 ab	-	38 a	-
G.16N	26 bcd	69 abc	25 ab	33 bc	56 ab	39 bc	24 ab	-	47 a	-
G.16T	28 bcd	68 bc	24 ab	29 bc	52 b	37 bc	30 ab	-	39 a	-
M.9 NAKBT337	17 d	69 abc	15 ab	14 c	39 b	30 bc	14 b	15 b	23 a	25 c
M.26 EMLA	20 cd	83 abc	10 b	29 bc	46 b	31 bc	16 b	13 b	-	29 bc
Supporter 1	30 bcd	58 c	15 ab	33 bc	51 b	33 bc	25 ab	28 c	36 a	41 ab
Supporter 2	37 bcd	65 c	20 ab	37 b	62 ab	23 c	20 ab	24 a	28 a	39 abc
Supporter 3	41 bc	66 c	18 ab	29 bc	55 ab	36 bc	28 ab	28 a	42 a	49 a
CG.3041	35 bcd	60 c	28 ab	31 bc	61 ab	40 abc	34 a	-	40 a	-
CG.5935	-	96 a	41 a	-	89 a	61 a	-	-	-	-

[1] Mean separation within column and cultivar by Tukey's HSD (P = 0.05).

[2] G.16N was originally propagated from stool beds, and G.16T originally came from tissue cultured plants.

closer look at the relative differences among rootstocks from site to site (Table 6) reveals very few important deviations from the effects reported in Table 2. Of note, M.9 NAKBT337 resulted in lower yield efficiency of 'Fuji' than expected in KY, and CG.5179 resulted in lower than expected efficiency in KY and PA-B. For 'McIntosh', Supporter 2 resulted in lower than expected yield efficiency in VT.

The very modest effect these rootstocks had on fruit size was obvious in the individual site means (Table 7). At most sites the rootstock effect was nonsignificant. At those site where it was significant, little deviation occurred from the overall effects reported in Table 2.

CG.3041 and CG.5935

CG.3041 was included in eight 'Fuji' and eight 'McIntosh' plantings. Tree numbers, however, were low enough to cause it to be excluded from the core analysis. Trees on CG.3041 generally fit into the smallest size category (Table 4) and resulted in relatively high yields (Table 5) and yield efficiencies in the highest category (Table 6). Where there was an effect of rootstock on fruit weight, those from trees on CG.3041 were in the largest category.

CG.5935 was included in four 'Fuji' and four 'McIntosh' plantings. Survival of trees on CG.5935 was not reduced at any site (Table 3). Tree size was similar to or somewhat smaller than those on CG.4013 (Table 4). In all cases, trees on CG.5935 yielded in the highest category, and in all but WA, trees on CG.5935 had the highest yield at each location (Table 5). Yield efficiency and fruit weight of trees on CG.5935 was always in the highest category (Table 6).

Discussion

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 (3, 4) and the Pillnitz Rootstock Breeding Program (2). These data position these new rootstocks into one of four distinct size categories: small semidwarf, large dwarf, moderate dwarf, and small dwarf. Obviously, the distribution among these categories is preliminary, since relative differences may change somewhat in the remaining years of the trial. Trees on CG.4013 were semidwarfs, larger than those on M.26 EMLA. Trees on CG.5202 and CG.5935 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 and CG.5935 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 to trees on M.9 NAKBT337. 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. (7, 8, 9) placed the G and CG stocks in similar categories to those reported here. Likewise, Fischer (1, 2) categorized the Supporter stocks consistent with the results of this trial.

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Table 6. Cumulative (2001-03) yield efficiency (kg/cm² TCA) of 'Fuji' and 'McIntosh' apple trees by location 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.[1]

Rootstock	CA	KY	MO	NC	OH	PA-B	UT	PA-R	SC	WA
					'Fuji'					
CG.4013	0.20 b	1.45 bc	0.69 b	0.62 b	0.08 a	1.27 bc	1.09 ab	-	-	0.70 a
CG.5179	0.86 a	1.35 bc	0.95 ab	0.89 ab	0.06 a	1.21 c	1.18 ab	-	2.01 a	0.73 a
CG.5202	0.31 b	1.27 bc	0.53 b	0.50 b	0.06 a	1.25 bc	0.67 b	-	-	-
G.16N [2]	0.39 b	1.95 abc	0.92 ab	0.93 ab	0.03 a	1.69 abc	1.83 a	-	0.99 b	1.04 a
G.16T [2]	0.40 b	1.73 abc	1.07 ab	1.10 ab	0.05 a	1.87 abc	1.67 a	-	-	1.19 a
M.9 NAKBT337	0.49 b	1.46 bc	1.31 ab	0.66 ab	0.04 a	1.52 abc	1.89 a	1.16 b	1.28 ab	1.09 a
M.26 EMLA	0.20 b	1.08 c	0.58 b	0.46 b	0.05 a	1.64 abc	1.04 ab	0.69 b	-	0.76 a
Supporter 1	0.64 ab	2.59 ab	1.16 ab	0.69 ab	0.03 a	2.23 a	1.54 a	2.05 a	1.49 ab	1.25 a
Supporter 2	0.60 ab	1.86 abc	1.38 a	0.76 ab	0.01 a	2.09 ab	1.48 a	1.87 a	1.48 ab	1.37 a
Supporter 3	0.39 b	2.84 a	1.45 a	0.74 ab	0.03 a	1.94 abc	1.51 a	2.23 a	1.66 ab	1.42 a
CG.3041	0.37 b	2.41 abc	1.11 ab	1.32 a	0.07 a	1.75 abc	1.17 ab	-	-	-
CG.5935	0.58 ab	-	-	1.05 ab	0.12 a	-	-	-	-	0.73 a
	MA	MI	MN	NS	NY-W	VT	WI	NY-P	ON	PA-R
					'McIntosh'					
CG.4013	2.19 a	1.59 cd	1.16 a	2.23 a	1.21 cd	1.87 abc	1.60 ab	-	0.94 a	-
CG.5179	2.25 a	2.15 ab	1.20 a	1.85 a	1.79 abcd	2.05 abc	1.79 a	-	0.98 a	-
CG.5202	2.01 ab	1.46 d	1.05 a	1.67 a	1.00 d	1.35 bc	1.44 ab	-	0.91 a	-
G.16N	1.82 ab	2.20 ab	1.31 a	1.79 a	2.39 a	1.98 abc	1.72 ab	-	1.63 a	-
G.16T	1.95 ab	1.93 bcd	1.15 a	1.94 a	1.99 abc	1.76 abc	2.08 a	-	1.46 a	-
M.9 NAKBT337	1.89 ab	2.06 abc	0.98 a	1.57 a	1.91 abcd	2.35 ab	1.49 ab	1.33 a	0.87 a	1.01 ab
M.26 EMLA	1.19 b	1.88 bcd	0.35 a	1.55 a	1.41 bcd	1.38 bc	1.13 b	0.72 b	-	0.70 b
Supporter 1	2.42 a	2.17 ab	0.94 a	1.97 a	1.86 abcd	2.09 abc	2.21 a	1.49 a	1.39 a	1.42 a
Supporter 2	2.50 a	2.20 ab	1.04 a	2.21 a	2.19 ab	1.27 c	1.68 ab	1.54 a	1.31 a	1.44 a
Supporter 3	2.53 a	2.54 a	1.02 a	1.59 a	1.88 abcd	2.23 abc	1.80 a	1.42 a	1.77 a	1.53 a
CG.3041	2.14 ab	2.17 ab	1.18 a	2.06 a	2.30 a	2.65 a	2.16 a	-	1.22 a	-
CG.5935	-	2.23 ab	1.42 a	-	2.05 abc	2.46 ab	-	-	-	-

[1] Mean separation within column and cultivar by Tukey's HSD (P = 0.05).

[2] G.16N was originally propagated from stool beds, and G.16T originally came from tissue cultured plants.

Table 7. Average (2001-03) weight (g) of fruit harvested from 'Fuji' and 'McIntosh' apple trees by location 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.[1]

Rootstock	CA	KY	MO	NC	OH	PA-B	UT	PA-R	SC	WA
					'Fuji'					
CG.4013	182 ab	152 a	213 a	199 ab	170 a	204 a	193 a	-	-	230 a
CG.5179	189 ab	146 a	207 a	205 ab	198 a	207 a	188 a	-	169 a	251 a
CG.5202	176 b	146 a	229 a	198 ab	186 a	194 a	186 a	-	-	-
G.16N [2]	179 ab	155 a	210 a	219 ab	241 a	190 a	198 a	-	175 a	253 a
G.16T [2]	193 ab	151 a	222 a	198 ab	194 a	206 a	190 a	-	-	222 a
M.9 NAKBT337	199 a	169 a	204 a	200 ab	159 a	203 a	205 a	189 a	178 a	240 a
M.26 EMLA	201 a	153 a	215 a	199 ab	189 a	184 a	185 a	171 a	-	236 a
Supporter 1	177 ab	142 a	199 a	160 c	150 a	172 a	207 a	165 a	158 a	216 a
Supporter 2	181 ab	149 a	197 a	168 bc	152 a	175 a	205 a	171 a	155 a	220 a
Supporter 3	175 b	144 a	195 a	172 bc	175 a	180 a	213 a	172 a	167 a	221 a
CG.3041	180 ab	187 a	222 a	222 a	186 a	186 a	184 a	-	-	-
CG.5935	188 ab	-	-	197 abc	176 a	-	-	-	-	228 a
	MA	MI	MN	NS	NY-W	VT	WI	NY-P	ON	PA-R
					'McIntosh'					
CG.4013	160 ab	172 a	129 a	131 abc	167 a	155 b	155 a	-	167 abc	-
CG.5179	158 ab	162 a	150 a	130 bc	163 a	156 b	149 a	-	166 abc	-
CG.5202	160 ab	166 a	137 a	139 abc	175 a	158 ab	152 a	-	158 abc	-
G.16N	157 ab	162 a	125 a	140 abc	163 a	167 ab	140 a	-	156 abc	-
G.16T	144 ab	154 a	133 a	131 abc	174 a	157 ab	151 a	-	160 abc	-
M.9 NAKBT337	169 a	167 a	161 a	153 a	167 a	177 ab	127 a	164 a	177 a	188 a
M.26 EMLA	158 ab	173 a	141 a	151 ab	177 a	184 a	156 a	146 b	-	183 ab
Supporter 1	139 ab	160 a	137 a	136 abc	168 a	169 ab	154 a	145 b	167 abc	174 ab
Supporter 2	134 b	154 a	131 a	129 c	173 a	163 ab	155 a	148 b	151 bc	169 b
Supporter 3	146 ab	161 a	123 a	130 bc	160 a	169 ab	161 a	136 b	146 c	172 b
CG.3041	155 ab	155 a	150 a	140 abc	177 a	173 ab	146 a	-	174 ab	-
CG.5935	-	153 a	131 a	-	179 a	178 ab	-	-	-	-

[1] Mean separation within column and cultivar by Tukey's HSD (P = 0.05).

[2] G.16N was originally propagated from stool beds, and G.16T originally came from tissue cultured plants.

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To obtain nomination guidelines, please contact committee chairperson, Dr. Desmond R. Layne, Department of Horticulture, Clemson University, Clemson, SC 29634-0375; phone: 864-656-4961; fax 864-656-4960; e-mail: dlayne@clemson.edu. Nominations must be submitted by May 1, 2006