Journal of the American Pomological Society 60(2):69-83 2006

Performance of 'Gala' Apple Trees on 18 Dwarfing Rootstocks: Ten-Year Summary of the 1994 NC-140 Rootstock Trial

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Abstract

Eighteen dwarfing rootstocks, including six M.9 clones and two Vineland selections, were compared at 25 North American locations for 10 years. For most response variables, there was a highly significant location x rootstock interaction, so rootstock performance differed greatly from one location to another. The M.9 clones tested in this study had similar tree survival and yield efficiency (YE), but there were large differences in tree vigor. M.9 Pajam 2 and M.9 RN29 were nearly as vigorous as M.26, whereas M.9 Flueren 56 was least vigorous. Rootstocks could be grouped into five size categories. The most dwarfing rootstocks included P.22, M.27, P. 16 and B.491, and these likely lack adequate vigor for commercial production. The second most dwarfing group of rootstocks were B.469 and Mark which produce trees of similar size. A group of slightly more vigorous rootstocks included V.3, B.9 and M.9 Flueren 56. Rootstocks similar in vigor to M.9 NAKBT337 included P.2, M.9 EMLA, M.9 Pajam 1, and O.3. The most vigorous group of rootstocks in the M.26 size class included M.9 RN29, M.9 Pajam 2, and V.1. Cumulative yield tended to be positively related to tree size, but had relatively low yields for its size. YE was significantly affected by rootstock at 14 locations. Trees on Mark had high YEs at most locations, whereas trees on B.491 had low YEs at many locations.

Introduction

One of the most important factors influencing the profitability of an apple orchard is rootstock, because rootstock can influence tree vigor, yield, average fruit size, and tree mortality. Harper et al. (7) reported that for three out of four processing cultivars, trees on B.9 were more profitable than trees on M.26, M.9 EMLA, and O.3 when tree spacing was adjusted for tree size. Previous studies have shown that rootstock performance is weakly dependent on the scion cultivar at a given location, but may vary greatly from one location to another (1, 2). All of the commercially important apple rootstocks were developed in Europe and none are totally adapted to North American conditions.

The East Malling Research Station released M.9, which is currently the most commonly planted dwarfing rootstock in North America. Considerable visible mutation of M.9 has occurred and there are now more than 25 selected strains or clones of M.9 differing in morphology and growth habit. These may provide a range of tree vigor and productivity (20). In Europe, particular clones or rootstocks derived from M.9 are sometimes selected for specific apple-growing regions, because they are easily propagated and are available from local nurseries or because they are supposedly adapted to local growing conditions, but some European researchers reported little difference in productivity among the M.9 clones (5, 8, 21).

European rootstock breeding programs rely heavily on M.9 as a parent. Polish researchers released five cold tolerant dwarfing rootstocks from the cross of Antonovka x M.9, and in North America O.3 and G.30 also have M.9 as a parent.

[1] For location of authors, please see Table 1.

Before the NC-140 regional project was established in the late 1970s, rootstocks were evaluated in many North American locations, but results were difficult to compare, because many aspects of the experiments varied. The NC-140 technical committee has established more than 10 uniform apple rootstock trials in North America so variable results are related primarily to differences in local growing conditions. In each trial, M.9 was included as a standard, but thus far, no rootstock in the M.9 size class has outperformed M.9. Although the North American apple industry depends heavily on M.9, there is a need for a dwarfing rootstock with better tolerance to diseases and low temperatures and with less propensity to produce root suckers and burrknots. The NC-140 Project is the primary vehicle for importing rootstocks from around the world into North America. With the generous help of commercial nurseries, new rootstocks and trees are propagated for new trials. The purpose of this study was to evaluate the performance of 18 dwarfing rootstocks planted at 25 North American locations. This is the first uniform rootstock trial to evaluate new clones of M.9.

Materials and Methods

All trees were propagated by TRECO, Inc., Woodburn, OR and the scion was 'Treco Red Gala #42'. Trees were planted at 25 locations during the spring of 1994 and cooperators and locations are listed in Table 1. Trees were planted in a randomized–complete-block design at each location. Trees were assigned to blocks on the basis of trunk diameter measured before planting. Because trunk size was confounded in block, trunk size was considered to be a treatment. All locations had 10 trees of each of 14 rootstocks, but several locations did not receive trees on one to four rootstocks (P.22, B.469, M.9 Fleuren 56, and V.3). Pollinizer trees consisted of one tree each of 'Liberty', 'Starkspur Supreme Delicious', and 'Fuji' on M.26 EMLA per block. Each cooperator had a choice of two spacings: 2.5 x 4.5 m could be selected for low-vigor sites and 3.5 x 5.5 m for high-vigor sites. Trees were planted with bud union 5.0 cm above the soil surface. Trees were supported to a height of about 2.1 m and managed as Vertical Axes (10). Pest, fertility, and water management were per local recommendations.

Trunk circumference of each tree was measured each fall and trunk cross-sectional area (TCA) was calculated. Tree height and canopy spread were measured during the fall of 2003. Total number of fruit per tree and yield (kg/tree) were recorded each year and used to calculate average fruit weight (FW). Root suckers were counted and removed each fall. After defoliation in 2003, each tree was evaluated for scion rooting, and scion-rooted trees were eliminated from the data set. The percentage of the trunk circumference covered with burrknots was recorded for each tree.

Rich Marini organized data collection and analyses. Some cooperators did not send data for all response variables every year as indicated by footnotes in the data tables. The experimental design was a replicated randomized complete block, where initial trunk sizes (blocks) were nested in location. SAS's Mixed Procedure was used to perform an analysis of variance for each response variable, and the Slice Option was used to test equality of rootstocks within each location (11). The location x rootstock interaction was significant for all response variables. In the past when interactions were significant, ANOVAs were usually performed for each location and a multiple comparison was performed to compare rootstocks within a given location (17, 19). Such an approach to evaluating interaction loses much information because each analysis is performed on a small subset of data. The Slice Option uses the entire data set to generate a P-value for each location to test the hypothesis that

Table 1. Location and cooperators in the 1994 Dwarf Rootstock Trial.

Location	Cooperator	Planting Location
(AR) Arkansas	Curt R. Rom	Fayetteville
(BC) British Columbia	Cheryl Hampson	Summerland, Canada
(CO) Colorado	Alvan Gaus, Ron Godin	Hotchkiss
(IA) Iowa	Paul A. Domoto	Ames
(IL) Illinois	Mosbah M. Kushad	Urbana
(IN) Indiana	Peter Hirst	W. Lafayette
(ME) Maine	James R. Schupp, Renae Moran	Monmouth
(MA) Massachusetts	Wesley R. Autio	Belchertown
(MI) Michigan	Ronald L. Perry	Clarkesville
(NB) New Brunswick	Jean-Pierre Privé	Bouctouche, Canada
(NC) North Carolina	Michael Parker, Richard Unrath	Fletcher
(NJ) New Jersey	Winfred P. Cowgill, Jr.	Pittstown
(NYG) New York	Terence Robinson	Geneva
(NYH) New York	Edward Stover, Jim Scupp, Terrence Robinson	Highland
(ONT) Ontario	John Cline	Simcoe, Canada
(PA-B) Pennsylvania	George M. Greene, Robert Crassweller	Biglerville
(PA-RS) Pennsylvania	Robert M. Crassweller	Rock Springs
(SC) South Carolina	Gregory I. Reighard	Clemson
(TN) Tennessee	Charles A. Mullins	Crossville
(UT) Utah	J. Lamar Anderson	Farmington
(VA) Virginia	John A. Barden, Richard P. Marini	Blacksburg
(WA) Washington	Bruce H. Barritt	Wenatchee
(WI) Wisconsin	Teryl Roper	Sturgeon Bay

all rootstocks within that location are equal. Because SAS does not support a method of properly performing a multiple comparison with the Slice Option, a macro was written to compare rootstocks within each location with Tukey's HSD (P = 0.05) (M. C. Marini, personal communication). The Tukey's test is computed using the variances and covariances associated with a specific rootstock within a location. Several locations did not receive P.22, B.469, M.9 Fleuren 56, or V.3. Because the lack of those rootstocks created open cells, they could not be included in the statistical analyses. To generate LSmeans for those rootstocks, a second ANOVA was performed for each response variable with data from all 18 rootstocks and, for comparative purposes, the LSmeans for those sites are presented in the tables.

Results and Discussion

This was a long-term trial, and during the 10-year period some cooperators were forced to terminate the trial prematurely, or for various reasons, some data were not reported every year for all response variables. Data for the four rootstocks that were not tested at all locations were not included in the statistical analyses or the discussion, but means are reported for comparative purposes.

Tree survival. Tree survival was significantly influenced by rootstock at 45% of the locations (9 of 20) (Table 2) ($P < 0.05$). No tree mortality occurred in BC, MI, and NJ

Table 2. Tree survival (%) after ten growing seasons for 'Gala' apple trees on 18 rootstocks. All values are least-squares means, adjusted for missing cells. The interaction of rootstock and location was significant. Least-squares means are presented for all rootstocks, but V.3, M.9 Fleuren 56, B.469, and P.22 were not included in the statistical analyses because they were not planted at all locations. Data from GA, IN, NYH, and WA were not submitted for 2003, but are presented for 2002 and were not included in the statistical analysis.

Stock	**AR**	**BC**	**CO**	**IA**	**IL**	**MA**	**ME**	**MI**	**NB**	**NC**	**NJ**	**NYG**
M.26 EMLA	50	100	90	100 a	100 a	100 a	100	100	100 a	80 ab	100	100
V.1	100	100	100	100 a	100 a	80 ab	100	100	90 ab	100 a	100	100
M.9 RN29	100	100	100	80 ab	100 a	100 a	100	100	100 a	70 ab	100	100
M.9 Pajam2	80	100	100	100 a	100 a	100 a	70	100	100 a	60 b	100	100
M.9 Pajam1	90	100	100	100 a	100 a	100 a	100	100	100 a	90 ab	100	90
M.9 EMLA	60	100	100	90 ab	100 a	90 ab	100	100	70 bc	70 ab	100	100
P.2	70	100	100	90 ab	100 a	90 ab	90	100	70 bc	80 ab	100	90
O.3	80	100	80	80 ab	100 a	80 ab	90	100	50 c	80 a	100	80
M.9 T337	80	100	100	90 ab	100 a	80 ab	90	100	90 ab	40 c	100	100
B.9	80	100	100	60 c	100 a	100 a	90	100	100 a	100 a	100	90
MARK	90	100	100	90 ab	100 a	60 c	90	100	100 a	40 c	100	90
P.16	70	100	100	90 ab	80 ab	70 bc	90	100	80 ab	30 c	100	100
M.27 EMLA	80	100	100	80 ab	90 a	100 a	90	100	90 ab	90 ab	100	90
B.491	70	100	100	70 bc	60 b	90 ab	90	100	100 a	50 bc	100	90
P.22	90	100	90	90	100	80	90	100	- - -	50	100	100
B.469	80	100	100	90	90	90	60	100	- - -	20	100	90
M.9 FL56	50	100	- - -	- - -	- - -	90	- - -	100	- - -	50	100	100
V.3	70	- - -	- - -	- - -	- - -	- - -	- - -	100	- - -	70	100	70
P-value	- - -	*1.000*	*0.999*	*0.020*	*0.031*	*0.004*	*0.099*	*1.000*	*0.001*	*0.001*	*1.000*	*0.328*
Stock	**ONT**	**PA-B**	**PA-RS**	**SC**	**TN**	**UT**	**VA**	**WI**	**GA**	**IN**	**NYH**	**WA**
M.26 EMLA	100	100	100	50 c	90	50 bc	80 ab	60 b	60	60	100	90
V.1	100	100	100	100 a	90	100 a	100 a	90 a	100	100	100	100
M.9 RN29	100	100	100	50 c	90	80 ab	100 a	90 a	70	100	90	100
M.9 Pajam2	100	100	100	80 ab	90	90 a	100 a	90 a	60	90	80	90
M.9 Pajam1	100	100	100	100 a	90	90 a	90 ab	90 a	55	100	100	100
M.9 EMLA	90	100	80	40 c	100	70 bc	100 a	80 a	55	100	90	90
P.2	90	100	100	- - -	50	90 a	100 a	100 a	80	100	100	90
O.3	90	90	90	80 ab	80	60 c	80 ab	90 a	70	50	100	90
M.9 T337	90	100	100	10 d	100	80 ab	100 a	90 a	40	100	100	90
B.9	100	100	100	40 c	90	100 a	100 a	60 b	90	100	100	100
MARK	100	100	90	20 d	100	100 a	70 b	100 a	80	90	90	100
P.16	100	90	100	40 c	100	100 a	80 ab	100 a	90	70	90	100
M.27 EMLA	100	90	100	60 bc	90	90 a	90 ab	100 a	40	100	90	100
B.491	80	100	90	100 a	80	80 ab	90 ab	100 a	65	90	90	100
P.22	80	90	100	- - -	- - -	100	100	100	50	100	- - -	80
B.469	70	100	70	- - -	- - -	80	80	90	35	100	80	100
M.9 FL56	- - -	100	- - -	- - -	- - -	- - -	70	- - -	75	100	- - -	90
V.3	80	100	- - -	- - -	- - -	- - -	80	- - -	- - -	- - -	- - -	90
P-value	*0.353*	*0.998*	*0.468*	*0.001*	*0.598*	*0.001*	*0.019*	*0.001*	- - -	- - -	- - -	- - -

[z]Least-squares mean separation within location by Tukey's HSD (P = 0.05).

whereas substantial tree mortality was reported for MA, NB, NC, SC, and TN (Table 2). There was a strong location x rootstock interaction, so the influence of rootstock on tree survival was not very consistent from one location to another, but tree survival was relatively low on B.469 at many locations. For trees on M.9 Pajam1 and V.1, survival was at least 90% at all locations. Tree survival was particularly poor in the three southeastern locations (GA, NC, and SC). The cause of tree death varied with location. Tree death was caused primarily by fireblight in SC, wind breakage in WI, vole damage in IA, winter injury in NB, and other causes in MA, ME, and PA-RS. After five years, tree survival in this trial was significantly influenced by rootstock at only 32% of the locations (14), indicating that more than five years is needed to evaluate the influence of rootstock on tree survival.

In previous NC-140 trials the location x rootstock interaction was significant for most response variables, but the effect of location on tree survival has not been consistent across NC-140 rootstock trials. In the 1985 trial, tree mortality was greatest in IN, ME, NC, NY, GA, IL, PA, TN and VA (19). In the 1993 trial, locations with high mortality included KY, IN, OH, and TN (2). In the 1990 trial, high tree mortality occurred in MI (15). V.1 may be a good rootstock for the southeastern US, because it was the only rootstock with no tree mortality in AR, NC, SC, or GA. Although tree survival is probably the most important characteristic influencing the profitability of an orchard, data for tree survival are not always reported for rootstock trials (3, 4, 6, 9). Warmund (20) compared 11 M.9 clones plus B.9, Mark, M.27, V.1, and V.3, with 'Red Fuji' as the scion, on an apple-replant site. Little tree death was observed for the first five years, but after 10 years, tree mortality was 30% for M.9 Burgmer 756 and 984, M.9 Janssen, V.3, and B.9. No mortality was reported for M.9 NAKBT340 or M.9 Bergmer 751. Tree loss was primarily caused by high wind, but trees were not apparently injured by three winters with temperatures of -25 to -28° C. Results reported in the current study and those of Warmund (20) indicate that tree survival cannot be evaluated after only five years, and long-term trials are needed to identify the inherent weaknesses of new rootstocks.

Trunk cross-sectional area (TCA). There was a strong location x rootstock interaction, so it is difficult to make general comparisons of rootstocks. TCA was significantly influenced by rootstock at all 20 locations reporting data for 2003 (Table 3). Locations with large trunks included IL, NJ, NYG, and UT; locations with small trunks included BC, ME, NB, NC, and ONT. Rootstocks generally producing the largest trunks were M.26, M.9 Pajam 2, and V.1, whereas small trunks were produced by M.27, P.16, and B.469. General rankings for TCA, from highest to lowest for the five M.9 clones were: Pajam 2 = RN29 > Pajam 1 > EMLA > T337 > Flueren 56. Based on TCA, V.1 and M.26 produced trees of similar size, whereas M.9 Pajam 1, M.9 Pajam 2 and M.9 RN29 were slightly smaller than M.26. At most locations, trees on B.9 had smaller trunks than trees on M.9 NAKBT337, and trees on Mark usually had smaller trunks than those on B.9.

Based on the sums of ranks for the locations with the complete set of rootstocks, rootstocks could be grouped into five size categories. The most dwarfing rootstocks included P.22, M.27, P.16, and B.491, but these likely lack adequate vigor for commercial production. B.469 and Mark produced trees of similar size, and may be best suited to high-vigor sites and vigorous cultivars. In situations requiring less vigor than M.9 NAKBT337, a group of rootstocks including V.3, B.9, and M.9 Flueren 56 should be considered. A group of rootstocks similar in vigor to M.9 NAKBT337 consisted of P.2, M.9 EMLA, M.9 Pajam 1, and O.3. The most

Table 3. Trunk cross-sectional area (cm^2) of surviving trees after ten growing seasons for 'Gala' apple trees on 18 dwarfing rootstocks. P.22, B.469, M.9 Fleuren 56, and V.3 were not planted at all locations and were not included in the analysis. Data from GA, IN, NYH, OR and WA were not submitted for 2003, but are presented for 2002 and were not included in the statistical analysis. The interaction of rootstock and site was significant. All values are least-squares means, adjusted for missing cells. [z]

Stock	AR	BC	CO	IA	IL	MA	ME	MI	NB	NC	NJ	NYG	ONT
M.26 EMLA	56.3 ab	29.6 def	40.5 a	103.1 a	121.6 a	94.8 a	60.9 a	105.9 a	67.1 ab	58.5 b	128.0 a	91.2 b	73.1 a
V.1	102.6 a	46.4 a	40.6 a	98.2 a	115.9 a	104.3 a	59.6 a	117.8 a	70.9 a	96.9 a	130.1 a	106.6 a	73.7 a
M.9 RN29	96.6 a	22.4 gf	32.8 bc	74.3 bc	95.1 b	70.0 bc	37.5 b	82.6 bc	66.4 ab	45.2 c	102.2 a	82.6 bc	58.6 ab
M.9 Pajam2	81.1 ab	24.8 cde	36.9 ab	82.2 b	92.0 b	78.9 b	40.5 b	89.1 b	65.8 ab	49.8 c	100.7 a	85.9 b	51.2 bc
M.9 Pajam1	89.9 ab	20.8 cd	26.1 de	70.5 bc	92.6 b	63.9 c	35.0 bc	81.1 bc	61.6 abc	45.3 c	96.2 ab	78.8 bc	47.4 bcde
M.9 EMLA	67.2 ab	17.3 def	29.3 cd	73.5 bc	99.5 b	64.8 c	30.0 cd	83.2 bc	50.8 c	37.9 c	88.9 ab	74.0 c	56.8 abc
P.2	54.6 cd	21.6 cd	22.9 e	44.0 d	57.4 c	57.7 cd	29.2 cd	48.0 d	51.3 c	48.4 b	60.6 c	72.9 c	34.9 de
O.3	70.5 c	22.0 cd	24.3 df	68.8 bc	78.3 b	57.9 cd	35.8 bc	71.5 c	61.8 abc	74.1 ab	91.1 ab	68.2 cd	47.4 bcde
M.9 T337	73.5 ab	18.1 cde	23.6 e	68.6 bc	99.3 b	57.0 cd	25.3 d	68.2 c	51.9 c	46.2 bc	90.1 b	63.2 d	37.6 bcde
B.9	43.7 de	22. 4 cd	32.9 bc	41.9 d	50.4 c	41.6 e	39.0b	50.4 d	56.1 bc	43.9 c	65.6 c	57.9 d	42.6 bcde
MARK	41.6 e	16.7 def	17.2 f	40.0 d	41.8 c	37.6 ef	38.2 b	44.6 d	60.6 abc	42.2 c	57.9 c	40.4 e	40.0 bcde
P.16	30.9 ef	7.8 g	14.3 fg	31.6 de	33.3 cde	25.8 fg	16.6 ef	26.0 f	27.8 d	13.9 d	40.4 d	32.1 f	31.9 de
M.27 EMLA	19.5 f	10.4 b	10.7 h	19.6 ef	19.6 ef	14.0 gh	13.6 fg	18.9 g	32.4 d	14.2 d	31.5 e	19.7 gh	30.8 e
B.491	37.7 de	11.0 gf	13.4 gh	24.8 de	30.6 ef	20.8 gh	17.9 ef	28.1 f	35.5 d	17.4 d	43.3 d	24.2 fg	29.2 e
P.22	37.3	7.3	8.2	13.1 f	19.5	8.8	9.0	17.4	- - -	21.8	15.1	13.8	9.1
B.469	39.1	14.1	27.8	36.4 de	38.1	34.1	23.3	35.0	- - -	28.2	57.8	35.4	36.2
M.9 FL56	52.1	16.7	- - -	- - -	- - -	46.7	- - -	69.2	- - -	27.4	80.1	59.6	- - -
V.3	35.4	- - -	- - -	- - -	- - -	- - -	- - -	39.0	- - -	33.2	55.2	56.9	37.5
P-value	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*
Site	**PA-B**	**PA-RS**	**SC**	**TN**	**UT**	**VA**	**WI**	**GA**	**IN**	**NYH**	**OR**	**WA**	
M.26 EMLA	91.0 b	103.4 a	102.4 a	136.0 a	106.1 ab	103.9 b	104.5 a	39.4	30.7	37.4	36.9	76.0	
V.1	116.7 a	100.3 a	91.9 ab	91.0 bcd	116.9 a	122.2 a	90.2 b	49.2	53.9	53.8	31.8	86.8	
M.9 RN29	74.9 c	71.7 b	97.9 a	85.1 bc	113.6 ab	74.3 c	71.9 cd	34.4	52.2	39.7	32.9	58.5	
M.9 Pajam2	73.7 c	78.6 b	90.4 ab	83.1 cd	104.2 ab	73.1 c	68.2 cd	30.5	47.2	31.8	36.8	54.7	
M.9 Pajam1	71.2 c	75.2 b	85.5 ab	82.5 bc	94.7 bcd	70.2 c	64.2 cde	21.1	43.0	33.1	33.1	64.7	
M.9 EMLA	70.4 c	49.2 c	87.4 ab	57.9 cd	103.6 ab	66.4 cd	70.2 bc	22.8	43.8	33.7	29.5	53.4	
P.2	59.4 d	49.2 c	- - -	58.9 de	82.4 cd	52.4 e	66.7 cde	17.6	25.9	24.7	26.0	4.9	
O.3	71.4 c	72.5 b	77.0 ab	78.3 b	78.3 d	68.9 cd	63.2 cde	31.9	34.3	38.9	31.8	54.8	
M.9 T337	62.9 cd	55.5 c	66.3 b	73.3 bc	100.4 ab	60.5 de	59.4 de	17.8	45.9	28.9	20.9	59.0	
B.9	32.6 f	46.6 cd	18.6 c	60.4 de	50.3 e	40.2 f	56.2 de	22.4	30.0	20.1	33.0	34.8	
MARK	24.9 g	45.2 cd	12.8 c	56.1 de	33.4 efg	37.5 f	51.4 e	21.0	33.9	16.2	22.0	32.7	
P.16	21.6 g	23.0 e	18.0 c	35.9 cd	41.4 ef	19.7 gh	36.1 f	7.7	12.4	12.2	12.1	25.6	
M.27 EMLA	8.3 h	16.5 e	4.2 c	16.7 e	26.7 g	16.2 h	22.0 fg	21.1	10.2	9.4	18.9	18.1	
B.491	20.5 g	21.9 e	20.4 c	35.2 bc	36.5 ef	26.7 g	35.1 f	11.0	20.0	18.9	19.3	14.8	
P.22	14.1	9.0	- - -	- - -	16.8	11.8	12.4	8.4	11.3	- - -	11.2	17.6	
B.469	29.4	30.4	- - -	- - -	43.1	40.2	32.2	15.9	24.8	13.9	17.3	25.2	
M.9 FL56	55.8	- - -	- - -	- - -	- - -	42.7	- - -	21.4	34.0	- - -	19.7	45.7	
V.3	45.7	- - -	- - -	- - -	- - -	42.6	- - -	- - -	- - -	- - -	16.8	37.5	
P-value	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	- - -	- - -	- - -	- - -	- - -	

[z]Least-squares mean separation within location by Tukey's HSD ($P = 0.05$).

vigorous group of rootstocks, in the M.26 size class, included M.9 RN29, M.9 Pajam 2, and V.1. When sums of ranks for TCA after 5 years were plotted against sums of ranks after 10 years, there was nearly a straight-line relationship, indicating that the relative vigor of rootstocks can be evaluated reasonably well after just five years (data not presented).

Other research reports also indicate that the size-controlling effect of rootstocks varies with location. The Vineland rootstocks were compared in several trials. In Missouri, USA, TCA from largest to smallest was: V.1 > M.9 NAKBT340 > M.9 EMLA > M.9 RN29 > Mark > M.9 NAKBT337 > M.9 Pajam 1 > V.3 > B.9 > M.27 (20). In a Nova Scotia trial involving 12 rootstocks with four cultivars, after four years Mark was the most vigorous: B.9, V.1, and V.3 were similar in size but were more vigorous than M.9. M.9 was more vigorous than B.491, B.469, M.9 NAKBT337, P.2, P.22, and P.16 (6). In Massachusetts, the ranking of 'Ginger Gold' TCA after six years was: Mark = V.1 > B.9 = M.9 NAKBT337 = P.2 > V.3 = P.16 = P.22 = B.491 = B469 (3). In a 6-year Massachusetts trial, comparing five Vineland rootstocks to M.26 EMLA with 'McIntosh' as the scion, M.26 EMLA was 27% larger than V. 1 and 41% larger than V.3 (4). In a rootstock trial in the Czech Republic, where Pajam 1 and Pajam 2 were compared to M.9 with three cultivars, M.9 and Pajam 1 had similar TCA, where as Pajam 2 was 0 to 24% larger than M.9, depending on the cultivar (9). Wertheim (21) compared several M.9 clones with five different scion cultivars. He reported that M.9 clones grew similarly in the nursery, but after six years in the orchard, M.9 NAKBT337 was 2% larger than M.9 RN29 and 12% larger than M.9 Flueren 56. In Denmark, Calleson (5) compared 20 rootstocks with three scion cultivars and reported the following rankings for TCA: M.26 > B.9 > M.9 EMLA > M.9 Pajam 1 = M.9 Pajam 2 > M.9 Nic 29 > M.9 NAKBT337 > P.16 > P.22. These varying results from different trials strongly indicate that the relative vigor of rootstocks depends on local growing conditions, so rootstocks must be tested in many locations. Recent discussions of the NC-140 Technical Committee also suggest that there may be a wide range of tolerance of apple rootstocks to replant conditions. Most test plots in this trial, where information was provided, previously contained rosaceous crops and most were not fumigated before planting (Table 4).

Table 4. Site preparation before planting.

Location	Site Preparation
BC	Planted in grapes
CO	Planted in apples, then fumigated
IA	Planted in Prunus crops for 8 years
ME	Planted in apples
MA	Hay field for many years
NB	Plums and cherries for 10 years, followed by oats for 2 years
PA-RS	Planted in apples , then chisel plowed
SC	Planted in peaches
VA	Hardwood forest, then chisel plowed
WI	Planted in strawberries

Root suckers. As previously reported (14), the rootstock x location interaction was significant for root suckers (Table 5). Rootstock significantly affected root sucker development at only 7 of the 19 locations that reported root sucker data for the tenth year. Trees in IA, IL, NJ, PA-B, PA-RS, UT, and VA produced the most root suckers, whereas very few root suckers were reported for BC, CO, NC, NYG, ONT, and TN. Root sucker production for different rootstocks was very inconsistent from one location to another, but M.26, P.2, V.3, and P.22 produced few root suckers at most locations. In the 1993 NC-140 trial, B.9, O.3, and Mark produced more root suckers than did M.26 (1). Root sucker production is not often reported, but in one trial, suckering was more strongly related to scion cultivar than rootstock, and M.9 pro-

Table 5. Root suckers per tree for trees surviving in the tenth year (2003) for 'Gala' apple trees on 18 dwarfing rootstocks. P.22, B.469, M.9 Fleuren 56, and V.3 were not planted at all locations and were not included in the analysis. The interaction of rootstock and site was significant. All values are least-squares means, adjusted for missing cells.

Stock	BC	CO	IA	IL	MA	ME	MI	NB	NC	NJ
M.26 EMLA	0	1	0 d	7 de	1	0	0	0	0	0 b
V.1	2	2	8 bc	30 b	4	4	6	0	1	4 b
M.9 RN29	1	4	8 bc	24 c	4	1	7	0	2	7 b
M.9 Pajam2	1	8	16 a	30 bc	6	6	5	0	2	5 b
M.9 Pajam1	2	3	18 a	24 c	3	5	4	0	1	5 b
M.9 EMLA	0	2	4 d	4 e	2	0	1	0	1	0 b
P.2	1	0	0 d	2 e	1	1	0	0	1	1 b
O.3	2	2	10 ab	28 b	4	5	2	6	2	6 b
M.9 T337	1	3	7 bc	22 c	3	2	2	1	1	7 b
B.9	0	2	10 b	37 b	3	2	2	1	1	4 b
MARK	6	1	6 bc	65 a	3	2	4	3	1	16 a
P.16	3	1	18 a	32 b	6	3	3	7	0	21 a
M.27 EMLA	0	2	1 d	12 d	2	1	1	0	1	2 b
B.491	2	1	5 cd	12 d	3	1	1	1	1	1 b
P.22	0	1	1	3	1	1	1	- - -	1	0
B.469	0	2	8	18	1	2	1	- - -	0	2
M.9 FL56	1	- - -	- - -	- - -	3	- - -	2	- - -	2	29
V.3	- - -	- - -	- - -	- - -	- - -	- - -	1	- - -	0	2
P-value	0.999	1.000	0.001	0.001	0.999	0.999	0.996	0.984	1.000	0.001
Site	**NYG**	**ONT**	**PA-B**	**PA-RS**	**SC**	**TN**	**UT**	**VA**	**WI**	
M.26 EMLA	0	1	0 c	0 f	0	0	1 c	4 d	0	
V.1	4	4	10 b	26 e	4	1	14 b	26 bc	3	
M.9 RN29	1	4	16 b	52 c	3	0	13 b	41 a	0	
M.9 Pajam2	2	8	32 a	89 a	6	2	4 b	38 a	0	
M.9 Pajam1	1	4	9 c	45 c	5	1	6 bc	46 a	2	
M.9 EMLA	0	1	2 c	15 e	1	0	1 c	20 b	0	
P.2	1	1	6 c	3 ef	- - -	0	2 c	5 d	0	
O.3	1	4	11 b	63 b	4	0	11 b	22 c	1	
M.9 T337	4	2	17 b	41 cd	5	0	2 c	31 b	2	
B.9	1	1	6 c	24 e	0	4	18 b	26 bc	1	
MARK	2	3	21 b	32 de	1	5	20 a	42 a	3	
P.16	3	8	5 c	64 b	1	1	21 a	43 a	9	
M.27 EMLA	2	0	1 c	4 f	0	2	6 bc	7 d	1	
B.491	1	0	2 c	9 ef	0	2	19 b	9 d	2	
P.22	1	1	2	9	- - -	- - -	5	8	2	
B.469	2	0	3	32	- - -	- - -	7	22	1	
M.9 FL56	1	- - -	7	- - -	- - -	- - -	- - -	19	- - -	
V.3	2	1	2	- - -	- - -	- - -	- - -	3 d	- - -	
P-value	1.000	0.979	0.001	0.001	0.994	1.000	0.001	0.001	0.988	

[z]Least-squares mean separation within location by Tukey's HSD (P = 0.05).

duced more suckers than did M.27 (9). Another factor that may have suppressed root sucker counts at some locations is herbicide applications, such as glyphosate.

Tree size. The size of the scion can be influenced by orchard management practices, growing conditions, and rootstock, so it is difficult to determine the contribution of rootstock to tree size. For example, at some locations canopy spread was greater than the space between trees (NJ, PA-B, SC, and WI), so containment pruning may have been needed. Tree height and spread were significantly influenced by rootstock at all locations. Tree height and canopy diameter were greatest at IA, IL, MI, NJ, and TN, whereas smaller trees were produced in BC. In NJ the height of all trees except P.22 ranged from 4.2 m to 5.6 m, whereas in BC the range in tree height was only 1.5 m to 2.6 m. Trees on V.1 tended to be the tallest and trees on M.27, P.22, and B.469 were the shortest (Tables 6 and 7). In the Vertical Axe system, trees that are about 2.6 m to 3.5 m are most profitable, because they have enough canopy volume for high yields and trees are short enough to avoid

Table 6. Tree height (cm) of surviving trees after ten growing seasons for 'Gala' apple trees on 18 dwarfing rootstocks. P.22, B.469, M.9 Fleuren 56, and V.3 were not planted at all locations and were not included in the analysis. The interaction of rootstock and site was significant. All values are least-squares means, adjusted for missing cells.

Stock	**BC**	**CO**	**IA**	**IL**	**MA**	**ME**	**MI**	**NB**	**NC**
M.26 EMLA	240 bc	256 bc	502 a	325 a	400 a	362 a	444 a	344 b	341 ab
V.1	265 a	321 a	491 a	332 ab	400 a	348 a	442 a	356 ab	387 a
M.9 RN29	227 b	289 ab	405 c	298 a	358 bc	290 b	433 ab	322 b	324 b
M.9 Pajam2	234ab	299ab	457 bc	320 ab	360 b	289 b	421 ab	330 b	346 b
M.9 Pajam1	218 b	243 bc	464 bc	308 ab	354 bc	267 b	425 ab	342 b	312 b
M.9 EMLA	208 c	260 b	437 c	326 a	350 bc	297 b	415 ab	327 b	294 b
P.2	211 b	235 bc	309 de	288 b	354 bc	273 b	353 c	307 bc	349 a
O.3	225 b	218 cd	406 d	309 ab	365 ab	286 b	392 b	352 ab	350 b
M.9 T337	218 bc	227 c	439 c	314 ab	331 bc	262 b	387 b	325 b	302 b
B.9	245 ab	270 b	342 d	292 ab	317 c	354 a	396 b	368 a	335 b
MARK	194 cd	214 cd	293 e	278 bc	248 d	289 b	332 cd	299 bc	284 b
P.16	176 cd	189 d	307 de	276 bc	247 d	241 c	325 d	272 cd	177 c
M.27 EMLA	166 d	185 d	223 f	240 c	188 e	219 c	240 e	246 d	219 c
B.491	189 cd	182 d	310 d	277 abc	208 e	259 bc	316 d	276 cd	251 b
P.22	150	181	206	236	176	187	235	- - -	231
B.469	213	232	289	272	245	254	306	- - -	343
M.9 FL56	219	- - -	- - -	- - -	322	- - -	416	- - -	262
V.3	- - -	- - -	- - -	- - -	- - -	- - -	334	- - -	325
P-value	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*
Site	**NJ**	**NYG**	**ONT**	**PA-B**	**PA-RS**	**SC**	**UT**	**VA**	**WI**
M.26 EMLA	563 a	464 ab	382 a	394 b	418 a	439 a	465a	398 b	448 a
V.1	572 a	487 a	390 a	431 b	424 a	421 a	487 a	452 a	403 ab
M.9 RN29	548 a	428 b	332 b	379 b	365 bc	429 a	477 a	348 c	391 ab
M.9 Pajam2	564 a	465 ab	391 a	395 b	436 a	417 a	458 ab	359 bc	381 ab
M.9 Pajam1	557 a	474 ab	347 b	381 b	379 bc	399 a	457 ab	347 c	38 ab
M.9 EMLA	541 a	444 b	365b	381 b	387 ab	421 a	478 a	354 bc	407 a
P.2	487 b	422 c	275 c	324 a	304 d	- - -	427 bcd	288 de	38 ab
O.3	524 a	388 c	332 b	381 b	381 abc	413 a	412 cd	349 b	357 b
M.9 T337	538 a	445 b	337 b	393 b	341 c	374 b	481 a	318 cd	373 ab
B.9	498 b	440 b	376 ab	306 c	348 bc	272 c	375 d	300 d	40 a
MARK	428 c	324 d	300 c	265 d	289 d	344 b	273 e	273 e	322 c
P.16	417 c	349 cd	232 e	262 d	251 dc	255 c	352 d	230 e	312 c
M.27 EMLA	352 d	251 e	185 d	187 e	215 c	154 d	260 e	204 a	225 e
B.491	475 b	324 d	28 c	283 cd	290 d	292 bc	326 e	258 e	317 c
P.22	283	258	169	241	211	- - -	- - -	192	207
B.469	448	317	241	274	314	- - -	- - -	242	293
M.9 FL56	540	412	- - -	377	- - -	- - -	- - -	275	- - -
V.3	471	389	295	331	- - -	- - -	- - -	304	- - -
P-value	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*

[z]Least-squares mean separation within location by Tukey's HSD (P = 0.05).

costly ladder work (13). At most locations, the more dwarfing rootstocks, P.22, P.16, M.27, B.491, and B.469 produced trees less than 3.0 m in height, which may be too small for high yields in the Vertical Axe system. On vigorous sites, the more vigorous rootstocks, V.1, M.26, M.9 Pajam 1, and M.9 RN29 may produce trees that are too tall for Vertical Axe training.

Yield. Cumulative yield was significantly influenced by rootstock at every location, but there was also a significant rootstock x location interaction (Table 8). Cumulative yield was greatest in NJ, PA-B, PA-RS, MI, and WI, whereas yield was low in BC, CO, ME, TN, and NYH. Yield was generally related to tree size, and high yields were produced by M.26, M.9 Pajam1, M.9 Pajam2, and V.1,

Table 7. Canopy diameter (cm) of surviving trees after ten growing seasons for 'Gala' apple trees on18 dwarfing rootstocks. P.22, B.469, M.9 Fleuren 56, and V.3 were not planted at all locations and were not included in the analysis. The interaction of rootstock and site was significant. All values are least-squares means, adjusted for missing cells.

Stock	BC	CO	IA	IL	MA	ME	MI	NB	NC
M.26 EMLA	180 bc	234 a	320 a	315 ab	359 b	321 a	299 a	362 a	239 cd
V.1	232 a	251 a	322 a	321 a	392 a	321 a	308 a	350 a	306 a
M.9 RN29	187 b	219 a	299 a	304 ab	320 c	269 b	283a	348 a	204 cd
M.9 Pajam2	191 b	247 a	315 a	299 b	347 b	272 b	288 a	346 a	226 cd
M.9 Pajam1	176 bc	198 b	305 a	300 ab	315 c	257 b	279 ab	353 a	220 cd
M.9 EMLA	151 c	204 a	296 a	304 ab	313 c	24 b	293 a	342 a	204 d
P.2	153 bc	197 b	22 b	241 c	295 c	202 c	212 cd	321 ab	227 cd
O.3	197 b	198 a	290 a	278 b	298 c	260 b	263 bc	252 b	268 bc
M.9 T337	171 bc	205 a	300 a	309 ab	301 c	222 b	276 ab	342 a	201 cd
B.9	184 b	242 ab	223 b	248 c	260 c	275 b	241 c	323 a	212 cd
MARK	122 cd	163 b	207 b	208 d	250 c	260 b	19 d	336 a	193 d
P.16	119 d	164 b	214 b	223 cd	217 d	210 c	195 d	290 b	122 e
M.27 EMLA	100 d	109 c	172 c	151 e	166 e	157 c	143 d	256 b	125 e
B.491	143 c	147 b	211 b	228 cd	199 d	216 c	203 d	283 b	149 e
P.22	86	101	125	149	119	118	118	- - -	128
B.469	145	198	212	214	236	220	191	- - -	194
M.9 FL56	162	- - -	- - -	- - -	285	- - -	274	- - -	171
V.3	- - -	- - -	- - -	- - -	- - -	- - -	205	- - -	203
P-value	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*
Site	**NJ**	**NYG**	**ONT**	**PA-B**	**PA-RS**	**SC**	**UT**	**VA**	**WI**
M.26 EMLA	471 b	340 ab	272 a	379 b	344 a	354 b	315 a	330 a	385 a
V.1	495 ab	375 a	291 a	412 a	320 ab	378 a	323 ab	335 a	377 a
M.9 RN29	469 b	321 b	267 a	372 b	309 bc	380 a	326 a	289 b	357 ab
M.9 Pajam2	477 a	337 b	272 a	372 b	309 bc	381 a	321 ab	296 b	365 ab
M.9 Pajam1	498 ab	322 b	268 a	367 b	322 ab	410 a	306 ab	289 b	360 ab
M.9 EMLA	458 ab	319 b	261 ab	372 b	286 c	369 b	337 a	286 b	368 a
P.2	417 bc	320 bc	206 c	297 c	258 d	- - -	297 b	244 c	355 ab
O.3	471 a	303 c	252 b	362 b	300 bc	364 ab	301 ab	297 b	351 ab
M.9 T337	466 b	299 c	223 c	355 b	295 bc	330 b	320 ab	284 b	349 bc
B.9	411 bc	302 c	254 b	276 c	276 cd	127 c	281 b	258 b	317 c
MARK	408 c	234 d	226 bc	211 d	239 d	131 c	229 c	240 c	309 c
P.16	396 c	245 d	172 d	225 cd	200 e	163 c	266 c	188 d	25 c
M.27 EMLA	342 d	193 e	146 d	118 f	156 f	69 d	197 d	155 e	222 e
B.491	399 e	214 de	212 c	256 c	204 e	199 c	246 c	235 c	296 c
P.22	252	149	122	162	140	- - -	154	123	157
B.469	383	230	200	243	214	- - -	255	213	267
M.9 FL56	466	318	- - -	339	- - -	- - -	- - -	260	- - -
V.3	406	294	218	320	- - -	- - -	- - -	253	- - -
P-value	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*

[z]Least-squares mean separation within location by Tukey's HSD (P = 0.05).

whereas low yields were recorded for M.27 and P.22. At most locations cumulative yield was lower for P.2 than for the other rootstocks in its size class (M.9 T337, O.3, M.9 EMLA, and M.9 Pajam 1).

Yield Efficiency (YE). Cumulative YE was significantly influenced by rootstock at 14 of 20 locations (Table 9). Rootstock did not influence YE in BC, CO, ME, NB, PA-RS, and TN. Cumulative YE was highest in BC, IA, WI, and MI, whereas low YEs were reported in CO, ME, NB, and NC. Trees on Mark had high YEs at most locations, whereas trees on B.491 had low YE at many locations. In the most dwarfing size group, YEs were often higher for trees on P.22, P.16, and Mark than for trees on M.27, B.491, and B.469. Trees on the slightly more vigorous rootstocks (V.3, B.9 and M.9 Flueren 56) had intermediate YEs. In contrast, YE was higher

Table 8. Cumulative yield (kg/tree) for surviving trees after ten growing seasons for 'Gala' apple trees on 18 dwarfing rootstocks. P.22, B.469, M.9 Fleuren 56, and V.3 were not planted at all locations and were not included in the analysis. Data from AR, GA, IN, NYH, OR and WA were not submitted for 2003, but are presented for 2002 and were not included in the statistical analysis. The interaction of rootstock and site was significant. All values are least-squares means, adjusted for missing cells.

Stock	BC	CO	IA	IL	MA	ME	MI	NB	NC	NJ	NYG	ONT	PA-B
M.26 EMLA	121.7 ab	53.2 a	205.9 a	193.5 ab	331.3 a	113.8 a	326.4 b	127.2 ab	155.1 ab	306.1 a	304.2 a	139.1 b	204.3 a
V.1	157.9 a	56.7 a	201.0 a	192.2 ab	331.5 a	101.9 a	425.0 a	152.1 ab	174.1 a	332.6 a	354.6 a	169.3 a	262.7 a
M.9 RN29	130.4 ab	72.6 a	200.3 a	190.5 a	319.9 a	74.0 a	358.8 b	163.9 a	106.7 b	327.3 a	331.5 a	126.7 b	235.3 a
M.9 Pajam2	121.5 b	80.1 a	220.4 a	210.2 a	345.9 a	68.8 a	422.2 a	174.4 a	95.3 c	325.7 a	316.2 a	153.7 a	237.9 a
M.9 Pajam1	110.3 b	54.0 a	190.5 a	209.5 a	273.4 ab	57.1 b	387.1 ab	159.1 ab	104.0 b	341.2 a	266.2 ab	106.6 b	225.9 a
M.9 EMLA	93.2 b	58.0 a	226.9 a	229.5 a	263.3 b	65.0 a	375.6 ab	110.6 b	77.5 c	305.7 a	308.2 a	106.0 b	223.5 a
P.2	100.7 b	47.2 ab	119.3 b	196.7 a	230.4 b	46.6 b	239.4 c	97.5 b	154.6 ab	169.3 b	224.9 b	95.4 bc	134.7 b
O.3	111.1 b	47.1 ab	191.5 a	224.7 a	247.3 b	76.0 a	395.4 ab	123.4 ab	174.2 a	256.0 ab	226. b	117.2 b	232.4 a
M.9 T337	107.6 ab	51.3 ab	14.0 a	215.9 a	231.9 b	45.1 b	341. 2 b	100.5 b	61.9 c	294.3 a	260.6 b	115.0 b	189.3 a
B.9	119.3 b	54.0 a	100.6 b	208.5 a	174.2 c	87.6 a	251.3 c	112.0 b	170.2 a	202.2 b	248.2 b	127.7 b	137.6 b
MARK	75.0 cd	25.1 b	109.5 b	187.2 abc	116.0 c	70.3 a	261.0 c	141.1 ab	80.6 c	184.3 b	182.8 c	119.9 b	86.4 c
P.16	49.4 d	26.0 b	92.7 b	149.9 c	106.7 c	32.5 b	221.0 c	65.5 bc	23.5 c	166.6 b	179.1 cd	69.9 c	75.1 c
M.27 EMLA	45.6 d	20.7 b	43.0 c	90.7 d	66.1 d	19.6 bc	98.9 e	50.4 c	47.5 c	78.5 cd	70.1 e	37.0 cd	23.8 d
B.491	64.4 d	25.6 b	66.6 bc	118.6 d	88.6 d	41.7 a	158.8 d	74.3 b	54.0 c	152.7 b	109.0 d	76.3 c	85.5 c
P.22	34.2	12.6	32.5	8.8	36.2	9.7	9.7	100.5	41.6	51.6	56.5	52.9	36.8
B.469	5.9	43.3	72.7	16.5	131.1	37.6	194.2	- - -	24.3	126.5	136.4	80.8	112.0
M.9 FL56	97.3	- - -	- - -	- - -	224.2	- - -	336.4	- - -	46.9	273.6	256.3	13.6	203.8
V.3	- - -	- - -	- - -	- - -	- - -	- - -	270.3	- - -	106.9	171.4	193.1	81.6	181.4
P-value	*0.001*	*0.010*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*
Site	**PA-RS**	**SC**	**TN**	**UT**	**VA**	**WI**	**AR**	**GA**	**IN**	**NYH**	**OR**	**WA**	
M.26 EMLA	315.5 a	292.0 a	167.9 a	146.9 bc	225.3 b	293.3 b	355	201 1	102	330	270	285	
V.1	332.5 a	310.0 a	186.8 a	224.6 a	317.6 a	345.7 a	521	227	365	399	617	800	
M.9 RN29	292.4 a	187.1 b	116.6 ab	218.0 a	239.8 ab	375.6 a	555	59	199	346	271	296	
M.9 Pajam2	302.1 a	260.1 ab	185.4 a	213.0 a	205.7 b	381.2 a	499	226	184	362	257	278	
M.9 Pajam1	315.8 a	271.6 ab	143.2 a	201.7 a	217.7 b	342.2 a	587	99	197	358	288	294	
M.9 EMLA	173.0 c	194.0 b	67.0 b	192.0 a	212.2 b	359.8 a	433	13	178	352	259	365	
P.2	165.2 c	9.6 d	60.2 b	168.9 b	141.5 c	325.4 a	676	27	330	309	241	657	
O.3	226.9 c	226.5 b	127.7 a	163.9 b	212.1 b	326.8 a	816	67	102	347	181	350	
M.9 T337	241.4 bc	155.1 bc	133.2 a	187.4 a	189.3 bc	309.4 a	502	15	387	369	484	728	
B.9	191.6 c	32.5 cd	157.1 a	140.9 bc	123.6 c	219.5 b	335	24	140	330	252	292	
MARK	145.6 c	26.0 cd	70.6 b	87.6 c	103.9 c	298.4 ab	251	81	279	256	573	672	
P.16	81.6 d	54.8 c	59.1 b	137.5 b	6.5 d	227.1 ab	267	89	110	306	466	518	
M.27 EMLA	41.9 e	9.8 d	5.6 c	45.4 d	30.6 d	104.9 c	99	87	32	253	198	93	
B.491	99.1 d	9.1 c	54.5 b	83.2 cd	46.2 c	188.4 b	286	4	78	324	177	105	
P.22	20.1	23.0	- - -	34.7	23.4	63.6	338	21	93	- - -	426	213	
B.469	99.7	- - -	- - -	101.7	85.0	190.0	302	46	223	269	520	553	
M.9 FL56	- - -	- - -	- - -	- - -	122.9	- - -	479	64	339	- - -	546	694	
V.3	- - -	- - -	- - -	- - -	103.4	- - -	13	- - -	- - -	- - -	546	631	
P-value	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	- - -	- - -	- - -	- - -	- - -	- - -	

[z]Least-squares mean separation within location by Tukey's HSD (P = 0.05).

Table 9. Cumulative yield efficiency (kg/cm^2 TCA) for surviving trees after ten growing seasons for 'Gala' apple trees on 18 dwarfing rootstocks. P.22, B.469, M.9 Fleuren 56, and V.3 were not planted at all locations and were not included in the analysis. Data from AR, GA, IN, NYH, OR and WA were not submitted for 2003, but are presented for 2002 and were not included in the statistical analysis. The interaction of rootstock and site was significant. All values are least-squares means, adjusted for missing cells.[z]

Site	BC	CO	IA	IL	MA	ME	MI	NB	NC	NJ	NYG	ONT	PA-B
M.26 EMLA	5.2	2.7	4.6 a	2.9 c	3.1 b	2.6	3.4 c	2.6	3.1 bc	3.1 ab	3.6 b	2.8 bc	4.0 b
V.1	4.5	2.5	4.4 ab	2.9 c	3.1 b	3.0	3.7 c	2.7	4.2 a	2.9 b	3.3 b	3.3 b	4.2 ab
M.9 RN29	5.4	3.0	4.5 a	2.7 c	3.3 b	2.9	3.8 bc	3.0	3.0 bc	3.1 ab	3.7 b	2.7 bc	3.9 b
M.9 Pajam2	4.9	3.1	4.4 ab	2.8 c	3.4 b	2.7	3.7 bc	2.9	3.5 bc	2.9 b	3.6 b	2.9 bc	3.6 b
M.9 Pajam1	5.0	2.8	4.3 ab	3.0 bc	3.3 b	2.9	3.6 c	2.7	3.1 bc	3.2 ab	3.1 b	2.6 bc	4.0 ab
M.9 EMLA	5.2	2.8	3.7 bc	2.8 c	3.2 b	2.8	3.7 c	2.6	2.8 bc	3.2 ab	3.6 b	2.4 c	3.9 b
P.2	5.3	3.1	4.5 a	3.7 ab	3.5 b	3.5	3.8 bc	2.9	3.0 bc	3.3 ab	3.2 b	2.9 bc	3.9 b
O.3	5.2	2.8	4.5 a	3.4 b	3.3 b	3.1	4.4 b	3.0	3.8 b	3.2 ab	3.0 b	3.0 b	4.0 ab
M.9 T337	5.1	2.9	4.2 abc	2.8 c	3.0 b	3.0	3.6 c	2.6	2.8 bc	3.0 b	3.1 b	2.8 bc	3.6 b
B.9	5.1	2.9	4.3 ab	3.6 b	3.3 b	2.9	4.1 bc	2.4	2.7 c	3.8 a	3.6 b	3.2 b	4.1 ab
MARK	5.5	2.6	5.2 a	4.3 a	3.4 b	3.2	5.1 a	2.9	2.2 cd	4.0 a	4.4 a	4.1 a	4.6 a
P.16	4.8	2.4	4.2 abc	3.4 b	3.3 b	2.4	4.8 ab	2.7	2.2 cd	3.6 a	3.4 b	3.4 b	4.4 ab
M.27 EMLA	4.9	2.9	3.8 bc	4.3 a	3.4 b	2.5	4.4 bc	2.8	2.7 c	3.8 a	3.5 b	3.0 bc	4.6 a
B.491	4.7	2.9	3.4 c	3.1 bc	3.3 b	3.0	3.8 bc	2.6	1.9 d	3.8 a	3.4 b	3.3 b	4.0 ab
P.22	5.5	2.9	4.6	4.4	4.4	2.6	5.2	- - -	2.3	4.0	3.4	2.1	4.1
N.469	5.3	3.1	3.7	4.2	3.9	2.9	4.7	- - -	2.0	3.1	3.5	3.1	4.4
M.9 FL56	5.1	- - -	- - -	- - -	3.3	- - -	3.9	- - -	2.3	3.1	3.4	1.0	3.8
V.3	- - -	- - -	- - -	- - -	- - -	- - -	4.7	- - -	3.0	3.5	3.4	3.0	4.2
P-value	*0.10 9*	*0.667*	*0.001*	*0.001*	*0.024*	*0.148*	*0.001*	*0.887*	*0.001*	*0.001*	*0.040*	*0.001*	*0.043*

Site	PA-RS	SC	TN	UT	VA	WI	AR	GA	IN	NYH	OR	WA	
M.26 EMLA	3.6	4.4 a	2.8	3.1 b	3.1	3.5 b	6.1	1.0	3.0	9.6	7.8	4.3	
V.1	3.8	4.8 a	1.9	3.6 ab	3.2	4.0 ab	4.8	5.8	6.7	7.6	19.7	9.7	
M.9 RN29	3.9	3.5 b	2.5	3.6 ab	3.8	4.6 ab	5.6	3.3	4.0	10.0	8.5	5.3	
M.9 Pajam2	3.8	4.2 a	2.8	3.8 ab	3.4	4.6	6.1	3.5	4.0	10.2	7.9	5.1	
M.9 Pajam1	3.7	4.6 a	2.7	3.6 ab	3.7	4.4 ab	6.8	3.4	4.7	11.3	9.1	4.8	
M.9 EMLA	3.4	3.3 b	2.0	3.7 ab	3.9	4.1 ab	6.6	2.2	4.1	11.1	9.0	8.1	
P.2	4.1	1.2 c	2.0	4.4 ab	4.5	4.2 ab	12.7	2.4	8.5	12.8	24.9	15.9	
O.3	3.3	3.9 b	2.1	3.9 ab	3.4	4.5 ab	17.6	6.7	3.4	9.5	5.4	6.7	
M.9 T337	3.9	4.0 ab	2.1	3.7 b	3.6	4.3 ab	7.6	1.9	8.4	13.4	23.8	13.4	
B.9	3.9	4.2 a	2.3	4.7 a	3.9	3.5 b	7.3	2.4	4.9	17.4	8.5	8.8	
MARK	3.9	2.9 b	- - -	5.6 a	4.3	5.3 a	7.4	5.4	9.1	18.0	26.7	20.7	
P.16	3.8	4.4 a	2.3	4.8 a	3.6	5.0 a	12.9	4.4	10.1	28.5	38.5	20.0	
M.27 EMLA	3.6	3.5 b	2.1	4.7 a	3.6	4.8 ab	4.8	1.8	3.0	40.2	11.2	5.2	
B.491	3.7	4.9 a	2.3	4.1 ab	3.2	4.1 ab	9.7	2.0	4.0	20.1	9.3	6.6	
P.22	3.9	- - -	- - -	5.4	3.9	5.0	11.3	2.3	8.4	- - -	37.5	13.7	
B.469	3.5	2.6	- - -	4.6	4.0	4.7	10.0	2.6	9.6	19.1	30.1	22.3	
M.9 FL56	- - -	- - -	- - -	- - -	3.4	- - -	11.4	4.0	9.8	- - -	28.0	16.4	
V.3	- - -	- - -	- - -	- - -	3.4	- - -	0.5	- - -	- - -	- - -	32.8	17.2	
P-value	*0.65 9*	*0.001*	*0.087*	*0.001*	*0.087*	*0.001*	--- -	- - -	- - -	- - -	- - -	- - -	

[z]Least-squares mean separation within location by Tukey's HSD (P = 0.05).

for M.27, B.9, and Mark than for O.3 after 5 years in the 1994 NC-140 trial (12). In terms of tree vigor, the next most vigorous rootstocks included P.2, M.9 T337, M.9 EMLA, M.9 Pajam 1, and O.3, and all five of these rootstocks had intermediate YEs. When averaged over the 11 locations where rootstock significantly affected YE, average values for YE within this group ranged from 3.18 for M.9 EMLA to 3.63 kg.cm-2 for O.3. The group of most vigorous rootstocks included M.26, M.9 RN29, M.9 Pajam 2, and V.1, and all four had similar YEs. The six M.9 clones had similar YEs. Averaged over the nine locations that tested all six clones, the mean YE values ranged from a low of 3.26 for M.9 Flueren 56 to a high of 3.63 for M.9 RN29, but rootstock significantly affected YE only in ONT where M.9 Flueren 56 had a YE of only 1.0.

In a previous Missouri trial after 10 years, B.9 and M.27 had higher YE than the more vigorous M.9 EMLA, M.9 NAKBT340, and V.1 (20). Although there were differences among cultivars, Craig (6) reported relatively high YEs for P.2, P.16, and P.22 which were low in vigor. B.146, B.469, and B.491 were also relatively low in vigor but also had relatively low YEs. The most vigorous rootstocks, V.1 and V.2, had moderate YEs. Autio and Krupa found that V.1 and V.3 had YEs similar to M.26 EMLA in one trial (4), but of the 10 dwarfing rootstocks in the second trial, P.16 had the highest YE and V.3 had the lowest YE (3). In a trial involving three cultivars, YE was inconsistently affected by M.9 Pajam 1, M.9 Pajam 2, and M.9 (10). Although YE is often negatively related to rootstock vigor, this relationship is inconsistent, and the YE of rootstocks within a size class may also vary.

Fruit size is not reported in this paper because average fruit weight is often negatively related to YE and must be adjusted with analysis of covariance. As in a previous trial (14), the location x rootstock x YE interaction was significant for average fruit weight and this complex relationship will be discussed in a later publication.

Burrknots. Only five locations reported data for burrknots (Table 10) and the percentage of rootstock circumference covered with burrknots was significantly affected by rootstock in three of the five locations. Burrknot development was greatest in BC and VA, whereas IA and MA had little burrknot development. In BC and VA, Mark had the most severe burrknot development, whereas B.469, O.3, P.16, and the M.9 clones had relatively low incidence of burrknots. After the first five years of this trial, burrknot severity was affected by rootstock in 11 of 20 locations reporting data (14). At most locations, burrknot development was high for Mark and M.27. In a previous rootstock trial with 'Gala', burrknot severity on the scion was higher in NC than in VA, and severity was greater for trees on P.1 and O.3 than on M.27 (16), but burrknot severity did not appear to adversely affect tree growth or productivity.

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Table 10. Burrknot severity (% of the above ground portion of the rootstock covered with burrknots) for surviving trees after ten growing seasons for 'Gala' apple trees on 18 dwarfing rootstocks. P.22, B.469, M.9 Fleuren 56, and V.3 were not planted at all locations and were not included in the analysis. The interaction of rootstock and site was significant. All values are least-squares means, adjusted for missing cells. [z]

Site	BC	IA	MA	ME	VA
M.26 EMLA	14 b	4	2	3 b	11 ab
V.1	14 b	0	0	1 b	4 b
M.9 RN29	17 b	1	1	0 b	2 b
M.9 Pajam2	2 c	0	0	2 b	3 b
M.9 Pajam1	15 b	1	1	3 b	2 b
M.9 EMLA	4 c	0	1	0 b	2 b
P.2	12 bc	5	0	1 b	3 b
O.3	3 c	1	0	3 b	3 b
M.9 T337	13 bc	0	2	1 b	8 b
B.9	7 c	2	0	0 b	3 b
MARK	76 a	11	3	2 b	23 a
P.16	1 c	0	4	11 ab	1 b
M.27 EMLA	13 bc	4	14	14 a	12 ab
B.491	10 c	15	7	12 ab	15 ab
P.22	5	1	8	16	8
B.469	6	1	6	5	3
M.9 FL56	10	- - -	1	- - -	3
V.3	- - -	- - -	- - -	- - -	3
P-value	0.001	0.058	0.084	0.029	0.001

[z]Least-squares mean separation within location by Tukey's HSD ($P = 0.05$).

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CALL FOR WILDER SILVER MEDAL NOMINATIONS

The Wilder Committee of the American Pomological Society (APS) invites nominations for the 2006 Wilder Silver Medal Award. All active members of APS are eligible to submit nominations. The award was established in 1873 in honor of Marshall P. Wilder, the founder and first president of APS. The award consists of a beautifully engraved medal which is presented to the recipient at the annual meeting of APS, held during the ASHS annual meeting.

The Wilder Medal is presented to individuals or organizations that have rendered outstanding service to horticulture in the area of pomology. Special consideration is given to work relating to the origination and introduction of meritorious fruit cultivars. Individuals associated with either commercial concerns or professional organizations will be considered if their introductions are truly superior and have been widely planted. Significant contributions to the science and practice of pomology other than through fruit breeding will also be considered. Such contributions may relate to any important area of fruit production such as rootstock development and evaluation, anatomical and morphological studies, or noteworthy publications in any of the above subjects. Information about the award, past recipients, etc. can be found on the APS website at http://americanpomoloical.org/wilder1.html

To obtain nomination guidelines, please contact committee chairperson, Dr. Douglas Archbold, Department of Horticulture, University of Kentucky; phone: 859-257-3352; fax: 859-257-2589; e-mail: darchbol@uky.edu

Nominations must be submitted by May 1, 2006