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Early Performance of 'Cortland,' 'Macoun,' 'McIntosh,' and 'Pioneer Mac' Apple Trees on Various Rootstocks in Maine, Massachusetts, and Nova Scotia[1]

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Abstract

Trials were established in 1995 at three sites in the northeast region of North America, which included four apple (*Malus* X *domestica* Borkh.) cultivars ('Cortland,' 'Macoun,' 'Rogers Red McIntosh,' and 'Pioneer Mac') in all combinations on 10 rootstocks (B.146, B.469, B.491, M.9, M.9 NAKBT337, Mark, P.2, P.16, V.1, and V.3). Tree survival was high after five growing seasons except for trees on B.146 and B.491 in Maine and Massachusetts. Poor tree quality at planting probably explains most of the tree loss on these stocks. Tree size was not affected by cultivar or location, but was dramatically affected by rootstock. The largest trees were on Mark followed by V.1. The smallest trees were on B.469, B.491, and B.146. The M.9 clones, P.2, and V.3 were intermediate in size and similar in trunk cross-sectional area. The difference between the largest and the smallest trees was nearly seven-fold in Massachusetts and only three-fold in Maine and Nova Scotia. Cumulative yield and yield efficiency were greater in Massachusetts than at the other two sites. Trees on Mark had the greatest yield followed by V.1, M.9, V.3, M.9 NAKBT337, and P.2. Trees on B.469, B.491, B.146, and P.16 were the least productive. Trees on P.16 had the highest yield efficiency followed by trees on V.3, P.2, B.491, M.9, and M.9 NAKBT337. The least efficient trees were on B.469, Mark, V.1, and B.146. Fruit size was larger in Massachusetts than in Maine or Nova Scotia. Rootstock effects on fruit size of 'Cortland,' 'McIntosh,' and 'Pioneer Mac' were similar, with the largest fruit from trees on V.1, M.9, and V.3 and the smallest from trees on B.146. Rootstock did not affect fruit size of 'Macoun.' Several interactions between cultivar, rootstock, and location for the measured parameters were significant, but the level of variation explained by these interactions was small, compared to that explained by the main factors, and the practical importance of these interactions was minimal.

The climate in the northeast region of North America is characterized by short cool growing seasons, which can limit the precocity, tree size, and fruit size of apples. The 1984 study conducted by the NC-140 Technical Committee showed differences in rootstock performance between sites that were due, in part, to climatic differences (10, 13). Based upon NC-140 studies, plantings in the northeast region generally are less precocious after five years (10) and smaller after 10 years than those grown in warmer climates with longer growing seasons (13).

Northeastern apple growers are converting to high-density plantings on size-controlling rootstocks to remain competitive in the global apple market; however, trees grown in this region must be cold hardy, and have adequate vigor and precocity to hasten canopy establishment and productivity in the short growing season. While M.9 has become the predominant dwarfing rootstock (18), the level of vigor provided by M.9 is often sub-optimal for the northeast, and it lacks adequate hardiness. Several rootstock breeding programs have recently introduced dwarfing selections

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bred specifically for cold climates, including the Budagovsky (15), the Polish (4), and the Vineland (5) series.

Northeastern apple production is focused on 'McIntosh' and related clones (1). These cultivars have distinctive flavors that have a strong regional following, and are extremely difficult to grow in warm climates, providing a market niche that is somewhat insulated from global overproduction. While extensive and inter-regional trials such as NC-140 are valuable for rapidly evaluating and selecting promising rootstocks, cultivar x rootstock interactions are sometimes of horticultural importance (16, 17), suggesting that the performance of regional cultivars on new rootstocks should be evaluated. The objective of this study was to evaluate the performance of four regionally important apple cultivars on 10 dwarfing rootstocks at three geographically dispersed locations in the northeast. This report summarizes the results of these trials over the first five growing seasons.

Materials & Methods

In late April to early May of 1995, a trial was established at three locations (Figure 1): University of Maine Highmoor Farm in Monmouth, ME; University of Massachusetts Cold Spring Orchard Research & Education Center, Belchertown, MA; and Atlantic Food & Horticulture Research Centre, Kentville, Nova Scotia, Canada. Each planting consisted of seven replications of 'Cortland,' 'Macoun,' 'Rogers Red McIntosh,' and 'Pioneer Mac' in all combinations on B.146, B.469, B.491, M.9, M.9 NAKBT337, Mark, P.2, P.16, V.1, and V.3 rootstocks. The experiment was conducted in a randomized-complete-block split-split-plot design, with location and replication within location in the whole plot. Scion cultivar represented the split plot, and rootstock cultivar represented the split-split plot.

Trees were spaced 1.5 x 3.7 m and trained to individual stakes (extending 2.5 m from the soil surface) as slender spindles. Pests, fertility, fruit thinning, and water were managed according to local recommendations.

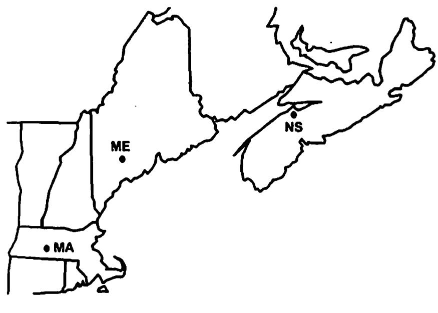

Figure 1. Approximate planting locations: University of Maine Highmoor Farm in Monmouth (ME), University of Massachusetts Cold Spring Orchard Research & Education Center in Belchertown (MA), and Atlantic Food & Horticulture Research Centre in Kentville (NS).

Trunk circumference was measured annually in October and consistently at the same point on each tree (between 25 and 50 cm above the soil surface). Trunk cross-sectional area was calculated from trunk circumference. Total yield was assessed for each tree in 1997, 1998, and 1999. Cumulative yield per tree was calculated as the sum of the 1997, 1998, and 1999 yields. Cumulative yield efficiency was calculated by dividing the cumulative yield per tree by the trunk cross-sectional area in October, 1999. Average fruit weight was calculated by dividing cumulative yield per tree by the total number of fruit from 1997, 1998, and 1999.

All data were subjected to analysis of variance with the MIXED procedure of the SAS software package (SAS Institute, Cary, NC). For these analyses, location (L), cultivar (C), rootstock (R), LC, LR, CR, and LCR were considered fixed effects, and replication (B:L), CB:L, RB:L, and CRB:L were considered random effects. Significant interactions were subjected to the SLICE option (by cultivar or location). Main-effect means were separated with Tukey's HSD (P = 0.05). Within interactions, t test was used to separate means, because it is the only option within the MIXED procedure of SAS capable of this level of separation. Because t test is overly sensitive when making all pairwise comparisons, the critical t value for declaring significance was adjusted upward to the value normally required at the P = 0.01 level.

Results & Discussion

Survival. Over the first five growing seasons of this trial, significantly greater tree loss occurred in Maine and Massachusetts than in Nova Scotia (Table 1). Most of the losses in Maine and Massachusetts were of trees on B.146 and B.491 (Table 2). Rootstock did not affect survival in Nova Scotia. Similar poor survival of trees on B.146 was not seen by Barritt et al. (3) with 'Golden Delicious,' 'Granny Smith,' and 'Delicious' or by Ferree et al. (7) with 'McIntosh,' 'Rome Beauty,' or 'Delicious.' The loss of trees on B.146 may have been at least partially the result of poor tree quality at planting, since these trees generally were small and weak. Cultivar did not affect tree survival (Table 1).

Tree size. Trunk cross-sectional area (TCA) after five growing seasons, was not affected by location or cultivar overall and was affected by rootstock (Table 1). The largest trees were on Mark, and the next largest were on V.1. The smallest trees were on B.469, B.491, B.146, and P.16. M.9, M.9 NAKBT337, P.2, and V.3 resulted in trees intermediate and similar in TCA. Overall, there was more than a fourfold difference from the smallest to the largest trees. Location (Table 3) and cultivar (Table 4) each interacted with rootstock to affect TCA, but relatively little variation from the overall order existed. However, the difference between the smallest (those on P.16) and largest trees

Table 1. Effects of location, cultivar, and rootstock on apple tree performance over the first five years after planting. All means are least-squares means adjusted for missing subclasses.[z]

Treatment	Survival (%)	Trunk cross-sectional area (cm^2, 1999)	Cumulative yield per tree (kg, 1997-99)	Cumulative yield efficiency (kg/cm^2TCA, 1997-99)	Average fruit weight (g, 1997-99)
Location					
Maine	93 b	9.3 a	11 b	1.17 b	153 b
Massachusetts	92 b	10.4 a	17 a	1.83 a	175 a
Nova Scotia	99 a	9.3 a	11 b	1.18 b	144 b
Cultivar					
Cortland	95 a	8.9 a	12 a	1.32 b	186 a
Macoun	94 a	9.5 a	14 a	1.54 a	152 b
McIntosh	95 a	10.2 a	14 a	1.44 ab	147 b
Pioneer Mac	95 a	10.1 a	12 a	1.28 ab	142 b
Rootstock					
B.146	74 c	5.0 de	5 e	1.09 d	137 d
B.469	97 ab	7.1 d	9 d	1.27 cd	157 abc
B.491	88 b	5.5 de	8 de	1.49 bc	153 bc
M.9	100 a	10.6 c	16 b	1.46 bc	165 ab
M.9 NAKBT337	98 ab	10.1 c	13 c	1.32 bcd	161 abc
Mark	99 a	18.8 a	23 a	1.20 d	159 abc
P.2	99 a	9.8 c	14 bc	1.49 bc	154 bc
P.16	93 ab	4.1 e	8 de	1.98 a	152 c
V.1	100 a	15.4 b	17 b	1.10 d	167 a
V.3	100 a	10.3 c	16 b	1.58 b	163 abc

[z]Within treatment type and within column, mean separation by Tukey's HSD (*P = 0.05*).

Table 2. Effects of location and rootstock on survival (%) of apple trees after the first five growing seasons. All means are least-squares means adjusted for missing subclasses.[z]

Treatment	Maine	Massachusetts	Nova Scotia
B.146	59 c	66 c	96 a
B.469	96 a	96 a	100 a
B.491	82 b	82 bc	100 a
M.9	100 a	100 a	100 a
M.9 NAKBT337	100 a	96 a	96 a
Mark	96 a	100 a	100 a
P.2	100 a	96 a	100 a
P.16	93 ab	86 ab	100 a
V.1	100 a	100 a	100 a
V.3	100 a	100 a	100 a

[z]Within column, mean separation by t test (*P* = *0.01*).

(those on Mark) was nearly seven fold in Massachusetts and only three fold in Maine and Nova Scotia.

The rootstock effects on TCA reported here closely reflect those reported by Marini et al. (8) for 1994 NC-140 Apple Rootstock Trial after five growing seasons. The only significant deviation from the results of the NC-140 Trial is for Mark. Trees on Mark in that study were comparable in size to M.9, V.3, M.9 T337, and P.2. The large size of trees on Mark in the study reported here is also at odds with a number of other assessments of the performance of Mark. For example, NC-140 (11) compared MAC.9 (Mark prior to virus indexing) with eight other rootstocks at 25 locations. On average, the TCA of trees on Mark after 10 growing seasons was about equal to that of trees on M.9 and smaller than the TCA of trees on M.9 EMLA. Generally, the same relationship existed after only five growing seasons (9); however, it was not consistent across location. At 10 out of 25 locations, trees on MAC.9 were numerically larger than comparable trees on M.9 EMLA, and at two locations (Massachusetts and Quebec), trees on MAC.9 were larger than those on M.26 EMLA. These two locations are roughly comparable in climate to the three locations in the study reported here. A reduced incidence of drought stress may be the climatic variable that resulted in greater relative growth of the trees on Mark in Massachusetts and Quebec in the NC-140 trial (11) and in the one reported here. Fernandez et al. (6) compared apple trees on various rootstocks and found that in response to drought stress, the growth rate of trees on Mark was reduced considerably more compared to the growth rate of trees on M.9 EMLA. Another possible explanation of the discrepancy between published reports concerning Mark rootstock and the data published here is misidentification. At the termination of this study, it likely will be necessary to use a molecular approach to positively identify the Mark trees.

Table 3. Effects of location and rootstock on trunk cross-sectional area (cm^2, 1999) of apple trees after the first five growing seasons. All means are least-squares means adjusted for missing subclasses.[z]

Treatment	Maine	Massachusetts	Nova Scotia
B.146	5.0 cd	3.6 e	6.3 fg
B.469	6.6 c	7.7 d	7.1 efg
B.491	5.7 cd	5.1 e	5.6 g
M.9	10.7 b	11.1 c	10.1 bcd
M.9NAKBT337	10.0 b	11.6 c	8.6 def
Mark	16.6 a	22.7 a	17.1 a
P.2	9.2 b	11.2 c	9.1 cde
P.16	3.7 d	3.3 e	5.4 g
V.1	15.8 a	18.2 b	12.2 b
V.3	9.9 b	9.6 cd	11.3 bc

[z]Within column, mean separation by t test (*P* = 0.01).

Yield. Cumulative yield per tree was greater in Massachusetts than in Maine or Nova Scotia (Table 1). Yield was not affected by cultivar, but both location (Table 5) and cultivar (Table 6) interacted with rootstock to affect cumulative yield. Neither interaction resulted in dramatic deviation from the overall effects of rootstock (Table 1). Trees on Mark yielded the most, followed by those on V.1, V.3, and M.9. The next lowest cumulative yields were from trees on P.2 and on M.9 NAKBT337.

Table 4. Effects of cultivar and rootstock on trunk cross-sectional area (cm^2, 1999) of apple trees after the first five growing seasons. All means are least-squares means adjusted for missing subclasses.[z]

Treatment	Cortland	Macoun	McIntosh	Pioneer Mac
B.146	4.6 ef	5.9 ef	4.9 ef	4.6 de
B.469	6.6 de	7.5 de	7.2 de	7.2 d
B.491	5.2 ef	6.0 ef	5.9 ef	4.9 de
M.9	8.7 cd	11.1 c	12.1 b	10.6 c
M.9 NAKBT337	9.2 c	9.3 cd	10.4 bcd	11.3 c
Mark	18.0 a	17.0 a	19.6 a	20.7 a
P.2	9.3 c	10.2 c	9.2 cd	10.6 c
P.16	3.2 f	4.4 f	4.5 f	4.5 e
V.1	14.1 b	14.3 b	17.5 a	15.7 b
V.3	9.9 c	9.5 cd	10.7 bc	10.9 c

[z]Within column, mean separation by t test ($P = 0.01$).

Lowest yields were from trees on P.16, B.491, B.469, and B.146.

Relating yield to tree size, yield efficiency was greater in Massachusetts than in Maine or Nova Scotia (Table 1). 'Macoun' trees were more yield efficient than 'Cortland' trees. Trees on P.16 were the most yield efficient, followed by trees on V.3, P.2, B.491, M.9, and M.9 NAKBT337. The least yield efficient trees were on B.469, Mark, V.1, and B.146. As with TCA and cumulative yield, location and rootstock interacted to affect efficiency (Table 7). The effects of rootstock in Massachusetts followed the overall effects, but the difference between the least and most efficient was about 2.5 times. None of the differences in Maine were significant, and only a few were significant in Nova Scotia; however, the trends were virtually the same as in Massachusetts. The high yield efficiency of trees on P.16 was observed previously by NC-140 (10, 12). The low yield efficiency of trees on B.146 has not been seen previously. Both Barritt et al. (3) and Ferree et al. (7) found trees on B.146 to have moderate to high cumulative yield efficiency after five growing seasons. The poor performance of B.146 reported here likely reflects poor tree quality at planting.

Fruit size. Fruit were larger on average in Massachusetts than in Maine or Nova Scotia, and 'Cortland' fruit were larger than fruit of the other cultivars (Table 1). Cultivar and location, however, interacted to affect size (Table 8). In Maine, 'Cortland' fruit were the largest, 'Macoun' fruit were significantly larger than 'Pioneer Mac' fruit, and 'McIntosh' fruit were intermediate. In Massachusetts, 'Cortland' fruit were the largest, and the other three cultivars were similar in size. In Nova Scotia, fruit size was not significantly different among the four cultivars. Rootstock also affected fruit size; however, it interacted significantly with cultivar (Table 9). Rootstock effects on 'Cortland,' 'McIntosh,' and 'Pioneer Mac' were similar, with

Table 5. Effects of location and rootstock on cumulative yield per tree (kg, 1997-99) of apple trees for the first five growing seasons. All means are least-squares means adjusted for missing subclasses.[z]

Treatment	Maine	Massachusetts	Nova Scotia
B.146	5 ef	5 d	6 e
B.469	8 def	10 c	9 cde
B.491	7 ef	11 c	6 e
M.9	13 bc	21 b	13 bc
M.9 NAKBT337	11 cde	18 b	9 cde
Mark	18 a	31 a	19 a
P.2	12 cd	19 b	11 bcd
P.16	5 f	10 c	8 de
V.1	16 ab	21 b	13 bc
V.3	13 bc	20 b	15 b

[z]Within column, mean separation by t test ($P = 0.01$).

Table 6. Effects of cultivar and rootstock on cumulative yield per tree (kg, 1997-99) of apple trees for the first five growing seasons. All means are least-squares means adjusted for missing subclasses.[z]

Treatment	Cortland	Macoun	McIntosh	Pioneer Mac
B.146	5 d	7 e	5 e	4 d
B.469	8 cd	9 e	10 cd	8 d
B.491	8 cd	10 de	8 de	6 d
M.9	11 bc	18 b	18 b	15 bc
M.9 NAKBT337	11 bc	13 cd	14 c	13 c
Mark	24 a	23 a	24 a	20 a
P.2	14 b	16 bc	14 c	13 c
P.16	5 d	8 e	9 de	9 d
V.1	15 b	16 bc	19 b	18 ab
V.3	14 b	17 bc	17 bc	16 bc

[z]Within column, mean separation by t test ($P = 0.01$).

the largest fruit generally coming from trees on V.1, M.9, and V.3 and the smallest from B.146. Rootstock did not significantly affect fruit size of 'Macoun.' Barritt et al. (3) showed a significant effect of rootstock on fruit size of 'Golden Delicious,' 'Granny Smith,' and 'Delicious.' As in the study reported here, V.1, M.9, and V.3 resulted in relatively large fruit, and B.146 resulted in relatively small fruit.

Conclusions

Evaluation of the early performance of rootstocks in this trial showed dramatic variation in tree size caused by these dwarfing rootstocks, ranging from the smallest trees on P.16 to the more than four-fold-larger trees on Mark. The largest trees yielded the most fruit, but had low cumulative yield efficiencies. P.16, on the other hand, resulted in the most yield efficient trees in the trial. B.146 resulted in a small tree, with low yields, low yield efficiency, and small fruit size.

One of the objectives of this trial was to assess the interactions of scion cultivar, rootstock, and location as they affect tree performance. Although some of these interactions were significant for the measured parameters, they were of little practical value. NC-140 (14) found significant interactions between scion cultivar ('Jonagold,' 'Golden Delicious,' 'Empire,' and

Table 7. Effects of location and rootstock on cumulative yield efficiency (kg/cm^2 trunk cross-sectional area, 1997-99) of apple trees for the first five growing seasons. All means are least-squares means adjusted for missing subclasses.[z]

Treatment	Maine	Massachusetts	Nova Scotia
B.146	1.05 a	1.26 d	0.95 b
B.469	1.20 a	1.39 d	1.21 ab
B.491	1.14 a	2.20 b	1.14 ab
M.9	1.20 a	1.94 bc	1.25 ab
M.9NAKBT337	1.10 a	1.80 c	1.05 b
Mark	1.09 a	1.41 d	1.09 b
P.2	1.35 a	1.86 bc	1.27 ab
P.16	1.31 a	3.16 a	1.47 a
V.1	1.01 a	1.20 d	1.09 b
V.3	1.30 a	2.12 bc	1.30 ab

[z]Within column, mean separation by t test ($P = 0.01$).

Table 8. Effects of location and cultivar on average fruit weight (g, 1997-99) of apple trees for the first five growing seasons. All means are least-squares means adjusted for missing subclasses.[z]

Treatment	Maine	Massachusetts	Nova Scotia
Cortland	190 a	218 a	151 a
Macoun	154 b	158 b	146 a
McIntosh	139 bc	163 b	139 a
Pioneer Mac	127 c	160 b	139 a

[z]Within column, mean separation by t test ($P = 0.01$).

Table 9. Effects of cultivar and rootstock on average fruit weight (g, 1997-99) of apple trees for the first five growing seasons. All means are least-squares means adjusted for missing subclasses.[z]

Treatment	Cortland	Macoun	McIntosh	Pioneer Mac
B.146	156 d	147 a	131 c	113 c
B.469	179 bc	161 a	143 abc	147 ab
B.491	187 abc	149 a	138 bc	140 ab
M.9	201 a	151 a	158 ab	149 ab
M.9 NAKBT337	187 abc	154 a	158 ab	147 ab
Mark	195 ab	148 a	148 abc	143 ab
P.2	189 abc	144 a	143 abc	141 ab
P.16	174 cd	164 a	139 bc	133 bc
V.1	197 ab	156 a	159 a	156 a
V.3	199 a	149 a	152 abc	153 a

[z]Within column, mean separation by t test ($P = 0.01$).

'Rome Beauty') and rootstock (M.9 EMLA, B.9, Mark, O.3, and M.26 EMLA) after five years. Many of these interactions dissipated by the end of 10 growing seasons (2). Further study will be needed to determine if the interactions seen in the present study also decline in significance.

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Promising Cornelian Cherries (*Cornus mas* L.) from the Northeastern Anatolia Region of Turkey

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Abstract

The objective of this research was to select valuable genetic resources of cornelian cherry (*Cornus mas* L.) grown in Northeastern Anatolia, Turkey from 1990 to 1996 for fruit size and yield. Approximately 1000 seedling trees were examined and 224 phenotypes having a fruit weight of 2.9 g and yield per cm^2 of trunk cross section area over 0.15 kg/cm^2 were selected in the first years (1990-1992). Thirty-one of these, found to be superior, were selected and evaluated for fruit characteristics. The ranges of the measured fruit characteristics for the selected phenotypes varied from 2.9 to 5.2 g for fruit weights, 6.0 to 9.4 for flesh/stone ratio, 11.5 to 16.8% for total soluble solids (TSS), 35.6 to 106.3 mg vitamin C/100 g, 1.5 to 4.7 % for total acidity (as malic acid) and 3.0 to 9.2 for TSS/acid ratio. These results suggest that the cornelian cherries selected may be suitable for commercial cultivation in the region. Many phenotypes were evaluated as promising for further breeding efforts.

Cornelian cherry is one of the commonly grown fruit species in Turkey. Most of trees are feral, but some are under cultivation. Cornelian cherry growing areas in the Northeastern Anatolia region are generally located around the river valleys. The Coruh river valley and its branches (Artvin and Erzurum provinces) have a large cornelian cherry population. Turkey grows 1,380,000 cornelian cherry trees, yielding approximately 12,800 metric tons per year. In the Artvin and Erzurum regions where this study was conducted, about 750 metric tons are annually harvested from the nearly 77,000 trees (2).

The cornelian cherry fruits have juicy, sour and sweetish taste. Fruits of this species are consumed fresh and are used to produce jam, jelly, stewed fruit, marmalade, pestil (a locally dried fruit pulp product), syrup and several types of soft drinks. The plant is also used for medicinal purposes due to the anti-diarrhetic properties of leaves and fruits (4). Ascorbic acid (Vitamin C) content of *Cornus mas* is 97.4 to 120.4 mg/100 g, over twice that of the orange (5).

In cornelian cherry culture areas of Turkey, there is a large number of native (seedling) phenotypes. These landrace trees have been selected from seed propagated trees for centuries. Because cornelian cherry is a cross-pollinated species (4, 5), many types have naturally occurred in different regions. Hence, Turkey has a wide genetic variation for this species. If high yielding and high quality fruit phenotypes were selected and propagated, cornelian cherry production could be increased.

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