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Performance of Ten Vigorous and Semi-Vigorous Apple Rootstocks Over Ten Years in British Columbia

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Abstract

A trial of 'Macspur McIntosh' on four seedling rootstocks (open-pollinated Antonovka, open-pollinated Haralson, Antonovka x Beautiful Arcade, Haralson x Beautiful Arcade) and six clonal rootstocks (B.118, I.48-41, M.2, M.4, M.7 and MO.56-4) was planted in 1986 to identify cold-hardy, yield-efficient apple rootstocks adapted to southern British Columbia. Spread and trunk cross-sectional area (TCA) were greatest for trees on MO.56-4 and smallest for trees on M.7. The height, spread and TCA of trees on the open-pollinated seedling rootstocks did not differ significantly, but TCA for trees on Haralson x Beautiful Arcade and Antonovka x Beautiful Arcade were smaller than on the open-pollinated seedling rootstocks. Trees on M.7 were the most precocious. Cumulative yield was high on MO.56-4, but its cumulative yield efficiency (cumulative yield/final trunk cross-sectional area) was among the lowest. Cumulative yield efficiency and canopy efficiency (cumulative yield/canopy volume over the last five years) were highest on M.7, M.4, and I.48-41. B.118 was similar to M.4 in height, spread, and TCA, but slightly lower in cumulative yield efficiency. All the seedling rootstocks were less precocious than M.7, and lower in cumulative yield efficiency than M.7 or M.4, but not M.2. Fruits from trees on Haralson x Beautiful Arcade and Antonovka x Beautiful Arcade were among the smallest. Rootstock did not affect the incidence of windfalls or the degree of bienniality of the scion. I.48-41, M.7 and open pollinated Haralson produced the most root suckers. Although yield performance was good on M.7, one of the trees died and another was seriously injured by a winter freeze during the study. Overall, M.4, B.118 and I.48-41 appear to have the greatest potential for cold sites.

Antonovka seedling rootstocks were planted commonly in southern British Columbia (B.C.) until the late 1980s because of their cold hardiness and resistance to crown rot. Haralson seedling rootstocks were also planted in B.C. during this period. A trial of standard to semi-vigorous rootstocks was initiated in 1986 to identify cold hardy, more yield-efficient, semi-vigorous rootstocks adapted to the region. Both seedling and clonal rootstocks were included in the trial.

Six clonal rootstocks were tested. Budagovsky 118 (B.118), from the Michurin College of Horticulture, Russia, was reported to be a cold-hardy rootstock resistant to crown rot and about equal to MM.106 in size-controlling ability (3, 4, 6). Pieniazek (8) noted that B.118 was precocious and more cold-hardy than Antonovka seedling. B.118 is easy to propagate in stool beds and is easily identified by its red leaves and bark (9). Morden 56-4 (MO.56-4) is an open-pollinated seedling of *Malus robusta* 5. Nothing is known of its performance as a rootstock, but it roots easily and was selected in a cold site. The clone I.48-41, from the North Caucasus Institute of Horticulture and Viticulture, Krasnodar, is reportedly comparable to M.26

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in vigor (8). Little is known about its performance, but it does not root easily in stoolbeds at Summerland (9). M.7, M.2 and M.4 from East Malling are rootstocks that have been used widely, M.7 for precocity and semi-vigorous size control, and M.2 and M.4 for productivity and crown rot resistance.

Materials and Methods

Four seedling rootstocks (open-pollinated Antonovka, open-pollinated Haralson, Antonovka x Beautiful Arcade, Haralson x Beautiful Arcade) and six clonal rootstocks (B.118, I.48-41, MO.56-4, M.2, M.4, M.7) were planted in a randomized complete block design with 10 replicates, using 'Macspur McIntosh' as the scion cultivar. Experimental units were single trees.

The Antonovka and Haralson trees used for seed source were located in the British Columbia Fruit Growers' Association Budwood Orchard, Research Centre, Summerland. Antonovka and Haralson seedling rootstocks are usually derived from open-pollinated seed. To determine if seedling rootstock performance could be improved by controlled pollination, crosses of Antonovka and Haralson with Beautiful Arcade were included in the trial. Trees on Beautiful Arcade seedlings are reportedly smaller than on other seedling rootstocks in Nova Scotia (5). All clonal plant material in the study came from virus-indexed sources, and was free of known viruses.

The stock was budded and grown for one year in the nursery. The trees were planted in 1986 at the same depth as in the nursery. They were headed at 0.7-0.8 m at planting and trained as free-standing central-leader trees. Side branches below 50 cm on the main stem were removed and those above 50 cm were cut back by one third. The following year, four to five scaffolds were selected, and the other branches were removed. The scaffolds and leader were tipped at that time. In subsequent years, more scaffolds were selected and tip-pruned, and weak or competing branches were removed. Trees were pruned annually during the dormant period.

The trees were planted at a spacing of 4.9 m x 4.9 m in a sandy loam soil. Standard orchard practices recommended for commercial growers in B.C. were imposed on the planting (2). Approximately 0.7 m of water was applied annually through microjet irrigation. Glyphosate and dichlobenil were used to maintain a weed free strip 1.2 m wide under the trees, and a mixture of orchardgrass and dwarf ryegrass was planted in the alleys. Ammonium nitrate was broadcast annually at 60-80 kg actual $N \cdot ha^{-3}$. Fruit were thinned chemically, with follow-up hand thinning.

Trunk cross-sectional area (TCA) was determined annually from measurements of trunk diameter at 10 cm above the ground. The height and spread of each tree were recorded annually. The spread was taken as the maximum extension of the canopy. Canopy volume was calculated from measurements of tree height and spread, and the height to the lowest scaffold branch on the tree, assuming a conical shape. Height, spread, and canopy volume reported in the tables were averaged over 1991-95 inclusive. The number of root suckers on each tree was recorded in 1987-89 and again in 1995.

The number of blossom clusters was recorded in 1988 and 1989, and bloom density (number of blossom clusters in 1988 + 1989/TCA in 1989) was calculated as a measure of precocity. Total fruit yield (kg) was recorded annually, and the cumulative yield determined at the end of the trial. Fruits were also counted in three years (1990, 1993, 1994) to obtain average apple size. Bienniality was gauged using the index described by Hoblyn et al. (7). Cumulative yield efficiency (CYE) was expressed as the ratio of cumulative

yield to final TCA, using post-harvest trunk measurements. Canopy efficiency was calculated as cumulative yield (1991-95) divided by canopy volume (1991-95), assuming a conical shape.

Data were analyzed statistically with the GLM procedure of the SAS software package (SAS Institute, Cary, NC), and means separated by the Waller-Duncan K-ratio T test (K-ratio = 100).

Results and Discussion

Tree size. Trunk cross-sectional area (TCA) ranged from 72-157% of the trees on M.4. TCA was largest for trees on MO.56-4, and smallest for M.7 (Table 1). The size range relative to M.4 was smaller for height and spread, probably because of pruning. None of the trees differed in height and spread (mean over 1991-95) by more than 10% from M.4, except for spread of trees on MO.56-4, which was 17% larger than M.4 (Table 1). Mean separation delineated several overlapping groups for height, spread and canopy volume, but MO.56-4 always ranked first and M.7 last.

Root suckers. The number of root suckers was variable and not normally distributed, but some trends emerged from four years of counts. None of the trees on B.118 or Haralson x Beautiful Arcade produced any root suckers (Table 1). Suckering was most prevalent on I.48-41, followed by M.7.

Flowering and yield. Precocity was estimated by blossom counts and bloom density. Trees on M.7 had substantially higher bloom density than trees on any of the other rootstocks (Table 2). Early yield is sometimes used to describe precocity, although it is actually a measure of early productivity, not precocity. Rank in yield was closely related to rank in precocity as measured by blossom number and bloom density, in spite of fruit thinning (data not shown).

Cumulative yield was highest on MO.56-4 and M.4, but CYE was high for M.4 and low for MO.56-4 (Table 3). Yield efficiency was also calculated on the basis of cumulative yield divided by (a) change in trunk cross-sectional area (1986-95) (b) above-ground tree weight. The Pearson coefficient for the correlation between TCA and fresh weight of above-ground wood was $R = 0.88^{***}$ when the rootstocks were pooled. Rank of the various rootstocks was the same or similar for all these calculations; therefore,

Table 1. Tree size and cumulative number of root suckers for 'Macspur McIntosh' on different rootstocks.[z]

Rootstock	TCA (cm^2)	Height (m)	Spread (m)	Canopy volume (m^3)	Number of root suckers
MO.56-4	211 a	4.3 a	4.8 a	23.2 a	9.6
Open-pollinated Haralson	168 b	4.1 ab	4.3 bc	17.5 bc	13.3
Open-pollinated Antonovka	164 bc	4.0 bc	4.1 cde	15.9 cd	0.5
M.2	154 bcd	4.1 ab	4.4 b	17.9 b	1.4
B.118	145 cde	4.0 bc	4.1 cde	15.5 de	0.0
Antonovka x Beautiful Arcade	143 de	3.9 cde	4.2 bcd	16.0 cd	0.1
Haralson x Beautiful Arcade	135 def	3.9 cde	4.0 def	14.4 de	0.0
M.4	133 ef	3.9 cde	4.1 cde	15.2 de	6.6
I.48-41	121 f	3.7 de	4.0 def	14.2 ef	44.0
M.7	96 g	3.7 de	3.8 f	12.6 f	21.0

[z]Values are means of 10 replicates. Mean separation by Waller-Duncan K-ratio t-test, K-ratio = 100. TCA = trunk cross-sectional area, year 10. Height and spread are means over five years (1991-95) and number of root suckers is mean cumulative count per tree over four years.

Table 2. Blossom cluster counts and bloom density of 'Macspur McIntosh' trees on different rootstocks.[z]

Rootstock	Blossom clusters per tree	Bloom density (clusters·cm^2)
M.7	173 a	6.4 a
MO.56-4	170 a	2.8 bcd
B.118	151 ab	3.9 b
M.2	133 abc	3.1 bc
M.4	132 abc	3.2 bc
I.48-41	118 bcd	3.3 bc
Open-pollinated Antonovka	99 cde	2.2 cd
Antonovka x Beautiful Arcade	98 cde	2.4 cd
Haralson x Beautiful Arcade	80 de	2.1 cd
Open-pollinated Haralson	72 e	1.7 d

[z]Values are: blossom clusters per tree = number of flower clusters in 1988 + 1989; bloom density = number of flower clusters (1988 + 1989)/TCA in 1989.

CYE is only presented on the basis of cumulative yield per cm^2 final TCA (Table 3).

Regardless of the calculation method, CYE was always high for M.7, M.4 and I.48-41 and low for M.2, MO.56-4 and the open-pollinated seedling rootstocks. The same was true of canopy efficiency (Table 3). In general, efficiency therefore was inversely related to tree size (TCA, height, spread, canopy volume), but the Haralson x Beautiful Arcade trees were exceptions (see discussion below).

Average fruit weight was measured in three different years, and differences among rootstocks were not extreme (Table 3). Haralson x Beautiful Arcade and Antonovka x Beautiful Arcade tended to rank low in average fruit weight. The incidence of windfalls was unrelated to rootstock ($P = 0.67$, data not shown).

Barritt et al. (1) found that rootstock vigor interacted with scion vigor and bearing habit to influence the degree of bienniality in the scion. For 'Smoothee Golden Delicious' (standard bearing habit) and 'Granny Smith' (tip bearer), bienniality was more severe with more vigorous rootstocks than dwarfing ones, but with 'Redchief De-

Table 3. Cumulative yield over 10 years, cumulative yield efficiency (CYE), canopy efficienty and fruit weight for 'Macspur McIntosh' on different rootstocks.[z]

Rootstock	Cumulative yield (kg)	CYE (kg·cm^{-2})	Canopy Efficiency (kg·m^{-3})	Fruit weight (g)
MO.56-4	354.6 a	1.69 cd	13.2 e	170 ab
M.4	323.3 ab	2.46 a	18.4 a	165 abc
B.118	295.1 bc	2.06 b	16.6 abc	172 a
I.48-41	291.1 bc	2.44 a	17.7 ab	163 abc
Open-pollinated Haralson	268.5 c	1.65 cd	13.4 e	167 abc
Haralson x Beautiful Arcade	263.7 c	1.99 bc	16.0 bcd	153 c
M.7	261.4 c	2.79 a	17.0 ab	173 a
M.2	260.9 c	1.73 bcd	12.7 e	162 abc
Antonovka x Beautiful Arcade	259.6 c	1.86 bcd	14.4 cde	157 bc
Open-pollinated Antonovka	252 2 c	1.60 d	13.9 de	165 abc

[z]Values are means of 10 replicates. Mean separation by Waller-Duncan K-ratio t-test, K-ratio = 100. CYE = cumulative yield (1986-95)/TCA in 1995; canopy efficiency = cumulative yield (1991-95)/mean canopy volume (1991-95). Fruit weight is mean over 3 years (1990, 1993, 1994).

licious' (a spur-type), the opposite was true. In this study, 'Macspur' showed a tendency for alternate bearing, with a bienniality index ranging from 0.13 to 0.35. However, there were no consistent differences among rootstocks (data not shown). The rootstocks used here were similar in size-controlling ability and semi-vigorous to vigorous, which may account for the absence of rootstock effect on bienniality.

Beautiful Arcade crosses. Crossing Beautiful Arcade with the Antonovka and Haralson seedling rootstocks significantly reduced the trunk diameter of the resulting plants relative to their open-pollinated counterparts (Table 1). Height, spread and canopy volume were also smaller in Haralson x Beautiful Arcade than open-pollinated Haralson. On average, Beautiful Arcade crosses had fewer root suckers than open-pollinated seedlings, especially for Haralson (Table 1).

Smaller tree size did not effect large improvements in CYE or precocity. The cumulative yield, blossom cluster number and bloom density of Beautiful Arcade crosses were no different from their open-pollinated counterparts (Tables 2 and 3). Although mean CYE tended to be higher in Beautiful Arcade crosses than open-pollinated seedlings of Antonovka and Haralson, the difference was statistically significant only for Haralson x Beautiful Arcade when CYE was calculated on a tree weight basis (data not shown). Haralson x Beautiful Arcade did show better performance than other seedling rootstocks and M.2 in canopy efficiency (Table 3), suggesting that lack of precocity may be responsible for its low CYE.

Beautiful Arcade crosses were comparable to B.118 and M.4 in all aspects of tree size (Table 1), but they were less precocious than B.118 (Table 2) and fell behind M.4 in cumulative yield, CYE, and canopy efficiency (Table 3).

All of the clonal rootstocks in this study, except MO.56-4 and M.2, showed better yield efficiency than the open-pollinated seedlings that have been used commonly in B.C. Using Beautiful Arcade as a pollen parent in crosses with Antonovka and Haralson did not greatly improve rootstock performance of the seedlings.

The M.7 rootstock produced the smallest, most precocious, most yield-efficient trees, but one of the 10 trees on M.7 died and another was seriously injured in 1991 by a winter freeze. I.48-41, M.4 and B.118, although slightly less yield-efficient than M.7, may therefore be better rootstock choices for cold sites. B.118 provides some advantage in terms of ease of propagation (9) and low root suckering. I.48-41 is slightly smaller and more yield-efficient than B.118, but tends to sucker. Whether B.118, M.4 and I.48-41 differ from each other in hardiness is unknown.

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