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Promising Early Results With Four New Apple Rootstocks from Quebec

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Abstract

Four cold-hardy apple (*Malus* × *domestica* Borkh.) rootstocks developed in Quebec, Canada (SJM-15, SJM-189, SJP84-5198, SJP84-5218) were tested for over seven seasons for their horticultural performance under Pacific Northwestern growing conditions in Summerland, British Columbia, Canada. Malling 9 (M.9, strain NAKBT337) and Budagovsky 9 (B.9) were included in the trial as standards of comparison. All trees were budded with 'Royal Gala', trained as slender spindles, and drip-irrigated. Tree survival was good for all the rootstocks. After seven years, trees on SJP84-5198 and SJP84-5218 were slightly larger than those on M.9 or B.9, while trees on SJM-189 and SJM-15 were similar to the standards in vigor. All the rootstocks had low amounts of root suckering, particularly SJM-189. Cumulative yield efficiency of the Quebec rootstocks equaled that of B.9 or M.9 after five cropping years. Fruit size was acceptable for all trees, but smallest on B.9 and largest on SJP84-5218. Fruit red color development was especially good for trees propagated on SJM-189. Further testing of these rootstocks is recommended.

Three series of Canadian-bred apple rootstocks exist. Greater winter hardiness than Malling 9 (M.9) was a major goal of all three series, combined with dwarfing ability and ease of propagation. The Vineland (V.) series consists of open-pollinated seedlings of 'Kerr', a winter-hardy, fire blight-resistant apple crab (Elfving et al., 1993). They have been tested for their resistance to fire blight (*Erwinia amylovora* [Burr.] Winslow) (Cline et al., 2001), tolerance to flooding and *Phytophthora* (Hampson et al., 2012), and horticultural performance in several different production areas in North America (Ferree et al., 1995; Marini et al., 2006a; Marini et al., 2006b; Hampson, 2012 and references cited therein). A current trial under the auspices of the NC-140 rootstock research group is testing V.5, V.6 and V.7 (http://nc140.org/plantings/2014applerootstock.html, accessed Dec. 3, 2015), which have not undergone much previous testing.

The other two series were developed mostly in Quebec (QC). The St Jean Morden (SJM) rootstocks actually originated at the Agriculture and Agri-Food Canada (AAFC) research center in Morden, MB in 1960 (Khanizadeh et al., 2005). After the closure of the apple rootstock breeding program at Morden, the seedlings were transferred to AAFC at St Jean-sur-Richelieu, QC, for further selection and evaluation (Khanizadeh et al., 2011b). The St Jean (SJP84) series arose from new crosses started in 1970 at Ottawa, which were also later transferred to QC (Khanizadeh et al., 2003; Khanizadeh et al., 2011a). These two series from QC have been characterized for their winter hardiness, and their resistance to woolly apple aphids (*Eriosoma lanigerum* Hausmann), crown and root rot (*Phytophthora cactorum* [Leb & Cohn] Schroeter), and fire blight in previous publications and online (Carisse and Khanizadeh, 2006; Canadian Food Inspection Agency, Plant Breeders' Rights Office, 2015; Khanizadeh, 2015). To the best of the author's knowledge, the horticultural performance of the QC rootstocks has only been evaluated in

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very small-scale trials in QC orchards with 'McIntosh' or 'Spartan' as scions (Khanizadeh et al., 2003; Khanizadeh et al., 2005).

The climates of the apple-producing regions in QC and British Columbia (BC) differ greatly. Quebec orchards are situated in a continental climate, with very cold, snowy winters, and moderate summer temperatures. In many areas, precipitation during the growing season is adequate for apple production without irrigation. BC's main producing area is the Okanagan Valley. The climate is semi-arid (< 30 cm annual precipitation, about half of which falls as snow), summers are warm, and direct insolation is high, so supplemental irrigation is a necessity. Winters are warmer than in QC, but snow cover is not always present in winter at elevations where orchards are planted. Past glaciation events have produced highly variable soils, but most are coarse-textured and low in organic matter, cation exchange capacity, and water retention.

The objective of this study was to evaluate the horticultural performance of four new dwarfing rootstocks from QC under the climatic conditions and prevailing cultural practices of the interior Pacific Northwest.

Materials and Methods

Plant material. Dr. S. Khanizadeh shipped greenhouse-grown rootstock liners of five dwarfing rootstocks (SJM-15, SJM-150, SJM-189, SJP84-5198, and SJP84-5218) from QC to BC in the spring of 2006. The parentage of the QC rootstocks is provided in Table 1. Approximately 8-10 liners of each clone were sent. They were planted in the field nursery of the apple breeding program at Summerland Research & Development Centre (49°34" N, 119°39" W, elevation 454 m). By Aug. 2006, the liners were still too small for budding, so they were kept in place and budded with 'Royal Gala' in 2007, along with liners of two standards: virus-free Malling 9 (M.9, strain NAKBT337) and virus-free Budagovsky 9 (B.9), both obtained from Golden West Nursery, Summerland, BC.

Orchard practices. In spring of 2009, the surviving trees were transplanted into east-west rows in a section of field devoted to testing apple breeding selections developed at Summerland Research & Development Centre (SRDC). This field had previously been planted to apple trees, and no fumigation or other pre-plant treatments were undertaken. The soil was a sandy loam.

The trees were planted with their bud union *ca*. 15 cm above the soil line, and were pruned and trained as short slender spindles, supported by wooden posts, at a spacing of 1.2 m x 3.7 m. No pollenizers were included, but the trial trees were surrounded by numerous different apple breeding selections.

The trees were drip-irrigated from May to Oct. annually, and managed according to regional recommendations for fertilization, irrigation, and pest control (BCMAL, 2010) as previously described (Hampson, 2012).

The trees were de-fruited after counting the blossom clusters in 2010 to encourage vegetative growth. In 2011-2015, the fruit were hand-thinned annually to single-fruit clusters 10-15 cm apart. Hand thinning was complete by the end of June each year (about 6-7 weeks post-bloom).

Table 1. Parentage[z] of the Quebec rootstocks in this study.

Rootstock	Female parent	Pollen parent
SJM-15	*Malus baccata* (L.) Borkh. var. Nertchinsk	Malling 9
SJM-150	*Malus baccata* (L.) Borkh. var. Nertchinsk	Malling 26
SJM-189	*Malus baccata* (L.) Borkh. var. Nertchinsk	Malling 26
SJP84-5198	*Malus* × *Robusta* 5	Malling 27
SJP84-5128	*Malus* × *Robusta* 5	Malling 27

[z] http://www.inspection.gc.ca/english/plaveg/pbrpov/cropreport/apple.shtml, accessed Dec. 3, 2015

Experimental design and data collection and analysis. The trees were planted in randomized blocks with single-tree replicates per block. The number of blocks was 7, but some of the QC rootstocks had fewer than 7 trees, because of transplanting losses in the field nursery in 2006, so the replication was unequal (n=5 to 7). Only one tree with SJM-150 rootstock survived; it was planted for observation only.

Trunk diameter was measured at planting and in autumn annually thereafter, at 30 cm above the bud union, and converted to trunk cross-sectional area (TCA) for analysis. In 2010 and 2011, the number of flower clusters per tree was counted. Floral density (number of clusters/TCA) was analyzed. Root suckers were counted annually and then removed. Apples were counted and weighed at harvest in the years 2011-2015. Dropped fruit were counted but not weighed. Crop load (fruit number/TCA), cumulative yield, cumulative yield efficiency, average fruit weight, tree height and canopy spread were all recorded or calculated as described elsewhere (Hampson, 2012).

'Royal Gala' is a multi-pick cultivar. At harvest, each tree was picked twice: once for fruit that were commercially ready according to ground color and overcolor, and a second time for all remaining fruit. The percentage of apples removed in the first pick was calculated each year on a fruit number basis. In 2012, 2014, and 2015, a 10-fruit sample from the "commercially ready" pick was collected from each of five replicate trees per rootstock. Mean fruit weight, diameter, and height were measured, and the height: diameter ratio was calculated. Firmness was measured by penetrometer (model EPT-1, Lake City Technical Products, Kelowna, Canada) on two sides of each fruit between sun and shade sides. The starch index was recorded on the Cornell generic starch chart (Blanpied and Silsby, 1992). The percentage of fruit surface with red overcolor was estimated visually and categorized as less than 25%, 25-50%, 51-75%, or over 75%, using the industry "Red Number 4" color intensity. This is equivalent to a color of L* 56.15, a* 37.22, b* 36.20 on the CIE L*a*b* color scale.

Field data were analyzed with the SAS procedure MIXED, with rootstock as a fixed effect and block as a random effect (SAS Institute, Cary, NC). Laboratory data were analyzed similarly but with both year and rootstock as fixed effects. Tukey's adjustment was used for mean separation purposes.

Results and Discussion

Tree survival and growth. Mortality was zero for trees on all rootstocks except M.9 and SJM-15, which each had one tree death (Table 2). The SJM-15 tree died in the first leaf. The M.9 tree died in the 7th leaf; it had signs of root problems (very small fruit, small leaves, late leaf-out) the year prior. The cause of death was not established with certainty for either tree.

The rootstocks differed slightly in TCA at planting (Table 2), from 0.55 cm^2 for SJM-189 to 1.29 cm^2 for SJP84-5198. These differences were statistically significant and large in relative terms (> 100%), but small in absolute terms (<1 cm^2). Initial TCA did not seem indicative of tree vigor later on: by the 7th leaf, the two SJP84 rootstocks had significantly larger TCA than M.9 or B.9, and the SJM rootstocks were intermediate. These trends in tree dwarfing capacity relative to M.9 were similar in trials done in QC (Khanizadeh et al., 2003; Khanizadeh et al., 2005; Khanizadeh et al., 2008).

Tree height was similar for all trees (Table 2). The M.9 and B.9 trees ranked last for canopy spread, but only SJP84-5218 was significantly wider. The trees were pruned in this trial, so height and spread rankings conceivably could vary slightly over years. However, the trend of trees on the two SJP84 rootstocks being the largest and trees on B.9 the smallest was similar in 2013 (data not shown).

B.9 has been inconsistent in trials at Summerland. In older trials, B.9 was between M.9 EMLA and M.26 EMLA in vigor (Hampson et al., 1997), but trees on B.9 were

Table 2. Least-squares means for initial trunk cross-sectional area (TCA), and the TCA, height, spread, and cumulative number of root suckers per tree after 7 years for 'Royal Gala' apple on different rootstocks.

Rootstock	Survival[z]	Initial TCA (cm^2)	Final TCA (cm^2)	Tree height (m)	Canopy spread (m)	Cumulative no. of suckers	Range in no. of suckers
B.9	7/7	0.85 bc[w]	13.39 b	2.09	1.34 b	6.9 ab	0 to 18
M.9	6/7	1.01 ab	12.33 bc	2.29	1.27 b	8.4 ab	0 to 28
SJM-15	5/6	0.69 bc	17.54 ab	2.24	1.70 ab	5.8 ab	0 to 18
SJM-189	6/6	0.55 c	15.53 ab	2.53	1.60 ab	1.1 b	0 to 3
SJP84-5198	5/5	1.29 a	19.87 a	2.49	1.78 ab	2.2 ab	0 to 4
SJP84-5128	7/7	0.91 abc	19.93 a	2.40	1.82 a	13.6 a	0 to 27
P value[y]		0.0005	0.0076	0.0587	0.0084	0.0377	
SJM-150[x]	1/1	0.58	25.43	2.79	1.93	0	0

[z] Number of living trees after 7 years/number of trees planted
[y] *P* value for differences among rootstocks
[x] Not included in statistical analysis
[w] Mean separation within columns by Tukey-Kramer adjustment for LS means in SAS MIXED procedure

"runted out" at the Summerland location of more recent trials (Autio et al., 2013; Marini et al., 2014), despite pre-plant fumigation treatment. Although they were statistically similar to trees on M.9-NAKBT337 in the size measures analyzed here, the trees on B.9 appeared to have less new shoot growth. All the other trees had vigor in the desirable range for high density plantings in the region.

Root sucker production was generally low (Table 2), and at commercially tolerable levels for a 7-year cumulative total. Individual trees had up to 28 suckers cumulatively, but for every rootstock, some trees had no suckers at all. Low propensity to sucker was also noted in earlier trials (Khanizadeh et al., 2003; Khanizadeh et al., 2005).

Flowering and productivity. Floral density is frequently used as a measure of precocity. Floral density was recorded in 2010 and 2011, but rootstock differences were only evident in 2010 (Table 3). Trees on all the QC rootstocks had lower floral density than trees on B.9 in 2010, and trees on SJM-189

Table 3. Least-squares means for floral density (spring 2010), cumulative yield, cumulative yield efficiency (CYE) and average fruit weight (AFW) for 'Royal Gala' apple on different rootstocks.

Rootstock	Floral density (no./cm^2)[z]	Cumulative yield (kg)	Cumulative yield efficiency (kg/cm^2)	Average fruit weight (g)
B.9	7.73 a[w]	40.5 c	3.13	183 c
M.9	6.90 ab	42.1 bc	3.26	198 b
SJM-15	4.82 bc	50.4 abc	2.95	198 b
SJM-189	4.11 c	49.2 abc	3.18	205 b
SJP84-5198	4.38 bc	64.3 ab	3.23	207 b
SJP84-5128	5.03 bc	68.0 a	3.46	221 a
P value[y]	0.0373	0.0014	0.5042	< 0.0001
SJM-150[x]	3.84	69.2	2.72	224

[z] Number of blossom clusters/trunk cross-sectional area
[y] *P* value for differences among rootstocks
[x] Not included in statistical analysis
[w] Mean separation within columns by Tukey-Kramer adjustment for LS means in SAS MIXED procedure

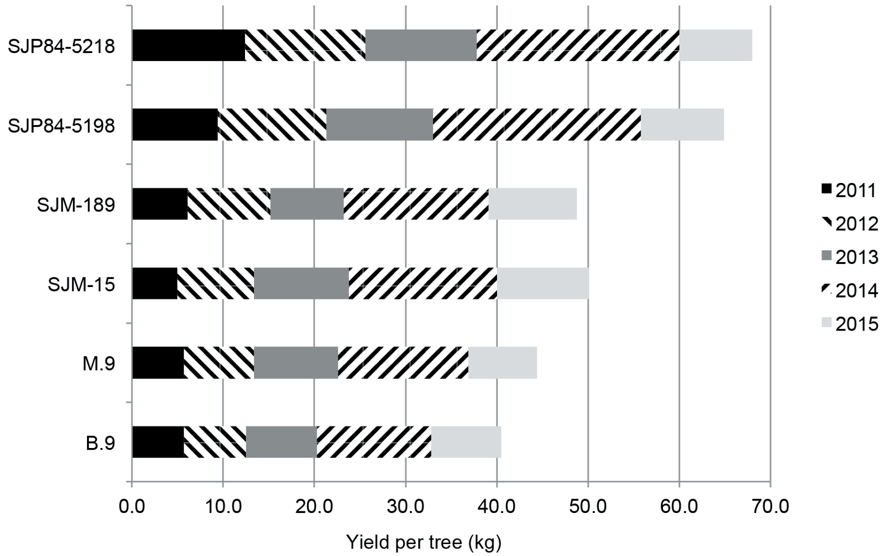

Fig. 1: Arithmetic mean yield per tree over five cropping years for six apple rootstocks.

had lower floral density than trees on M.9. However, this finding may not have practical relevance, because the trees were not allowed to fruit in their second leaf, in order to maximize vegetative growth.

Yields were recorded annually (Fig. 1) and cumulatively (Table 3). Dropped fruit were not included in the yield since there were very few (usually < 4 apples). Crop load was not significantly different among rootstocks in 2012 to 2014 inclusive (data not shown). In 2015, crop load on SJM-189 was greater than on SJP84-5218 (data not shown), but since crops were light on all trees that year (crop load ≤ 3.5 fruit/cm^2 TCA), crop load was unlikely to have affected fruit size in any of the five cropping years. Cumulative yield differences mirrored the differences in tree size, and cumulative yield efficiency (CYE) did not differ among rootstocks (Table 3). Prior reports also found the QC rootstocks to have high CYE, similar to M.9 (Khanizadeh et al., 2003; Khanizadeh et al., 2005).

Although productivity was therefore similar per unit TCA and crop loads were similar, fruit size differences were significant (Table 3). Trees on B.9 had the smallest fruit and trees on SJP84-5218 had significantly larger fruit than trees on either M.9 or B.9. Fruit size for trees on the other QC rootstocks was similar to trees on M.9. Previous trials did not find any significant difference in fruit size (Khanizadeh et al., 2003; Khanizadeh et al., 2005). The scion cultivar was different here than in the older trials. Moreover, in at least one of the QC reports, crop load was not adjusted.

Fruit quality. 'Gala' is a multi-pick cultivar, and harvest maturity standards are based in part on overcolor. The proportion of fruit that was ready for harvest on the first color pick was calculated annually starting in 2012. The main effects of year and rootstock and the year x rootstock interaction were all statistically significant, so means for each year are presented (Table 4). Overall, trees on SJM-189 and SJP84-5198 had a higher proportion of fruit in the first pick than trees on the standards M.9 and B.9, and there were differences among years in the proportion of fruit harvested in the first color pick. Inspection of annual means for each rootstock shows that despite some differences in rank from year to year, SJP-189 and SJP84-5198 were always the top two in rank, and fruit from trees on B.9 was always 5th or 6th in rank.

Laboratory measurements were conducted to detect whether internal maturity differences existed among rootstocks, and red color was rated on all of these apples. The percentage of fruit surface area occupied by red overcolor is depicted in Fig. 2 for 2014 and 2015. Because these fruit were sampled from the first color pick, all were considered sufficiently colored to meet minimum grade standards, but SJM-189 stands out as having particularly high color, especially in 2014

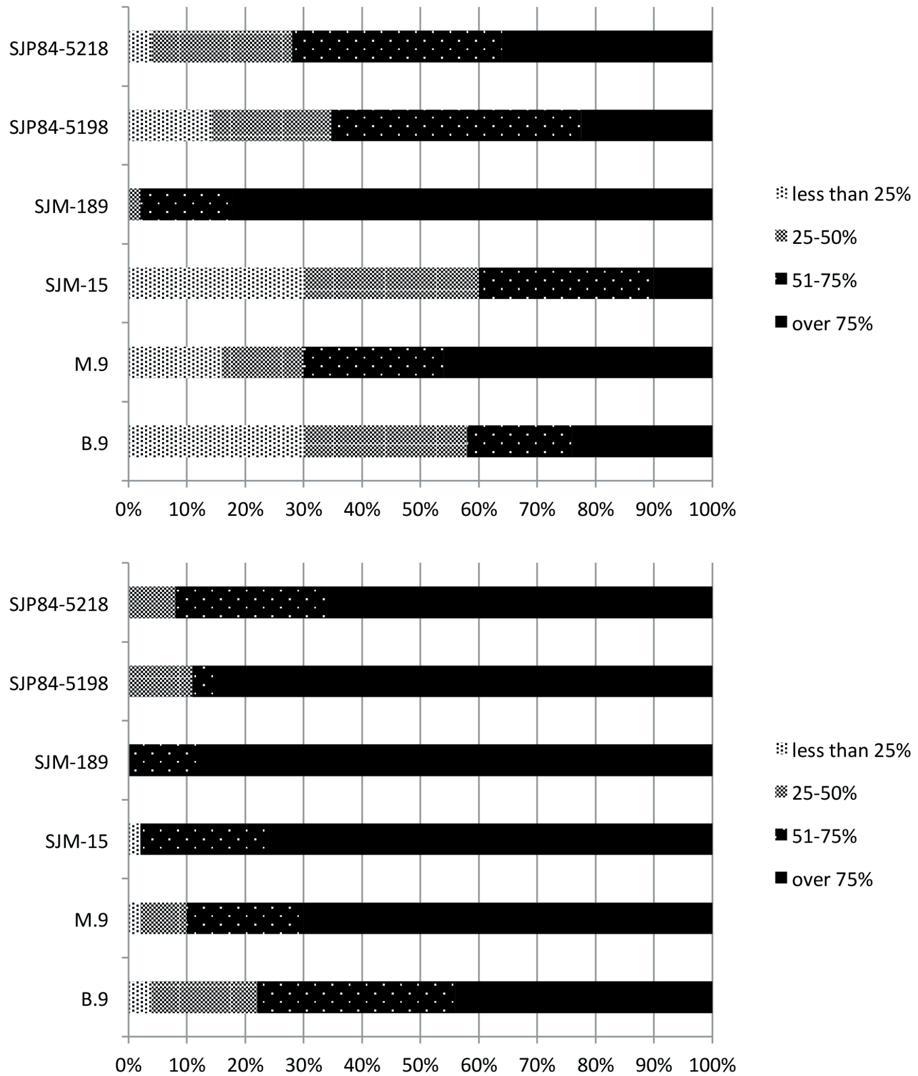

Fig. 2: The percentage of fruit surface area covered by red color intensity better than or equal to "Red No. 4" (n=5 replicates x 10 apples/replicate) in 2014 (upper panel) and 2015 (lower panel). Red No. 4 is equivalent to a color of L * 56.15, a* 37.22, b* 36.20 on the L*a*b* color scale.

Table 4. Least-squares means for the percentage of 'Royal Gala' fruit harvested in the first color pick over four years on different rootstocks.

Rootstock	2012	2013	2014	2015	Row mean
B.9	88.4 ab[y]	35.0 d	51.4 b	71.8	61.7
M.9	82.8 b	65.0 abc	55.4 b	70.0	68.3
SJM-15	94.9 ab	45.8 c	48.1 b	71.9	65.2
SJM-189	98.2 a	88.3 a	86.1 a	85.4	89.6
SJP84-5198	98.7 a	75.4 ab	63.2 ab	86.2	81.0
SJP84-5128	94.6 ab	71.0 abc	59.9 b	81.6	76.8
P value[z]	0.0164	<0.0001	0.0004	0.1572	
Column mean	93.3	63.0	60.8	78.0	

[z] *P* value for differences among rootstocks within column
[y] Mean separation within columns by Tukey-Kramer adjustment for LS means in SAS MIXED procedure

when average color (61%) was lower than in 2015 (78%, Table 4).

For internal quality measurements, year and rootstock main effects were both significant for all analyses except average fruit weight (Table 5), but in no case was the year x rootstock interaction significant. The observation of year-to-year differences is not surprising, given differences in weather, crop load, and maturity at harvest among years. Differences among rootstocks in average fruit weight (AFW) were similar to AFW trends from the field harvests (Tables 3 and 6). Fruit from trees on SJP84-5198 appeared to be slightly more advanced in maturity than fruit from trees on M.9 or B.9, based on starch index (Table 6). Flesh firmness was also slightly less for apples from trees on SJP84-5198 than B.9, although not different from trees on M.9. In the case of SJM-189, fruit internal maturity, as judged by starch breakdown or firmness, was similar to that of fruit from trees on B.9 or M.9 (Table 6), so the improved color could not be attributed to fruit maturity in this instance. Rootstock also affected fruit height:diameter ratio significantly, but the difference was small in absolute terms (Table 6). Apples from trees on SJP84-5198 and SJP84-5218 had a higher ratio (were "taller") than fruit on B.9, and the others were intermediate. No information about fruit quality or color was recorded in the trials done in QC (Khanizadeh et al., 2003; Khanizadeh et al., 2005).

Conclusions. The four new rootstocks from QC all performed well in a replanted orchard with respect to tree survival, vigor, and productivity, relative to standards M.9 and B.9. Root suckering was lowest for trees on SJM-189. All the QC rootstocks were equal to the two standards in yield efficiency. Fruit size was better than or equal to that of trees

Table 5. Least-squares means for laboratory samples of fruit from 'Royal Gala' apple over three harvests.[z]

Year	Weight (g)	Diameter (cm)	Height (cm)	Height: diameter ratio	Firmness (kg·F)	Starch index
2012	224	7.80 a[x]	6.91 c	0.89 c	8.99 a	3.4 b
2014	227	7.73 a	7.15 b	0.92 b	8.15 b	3.7 b
2015	223	7.51 b	7.46 a	0.99 a	8.39 b	5.4 a
P value[y]	0.8065	0.002	<0.0001	<0.0001	<0.0001	<0.0001

[z] Averaged over all rootstocks
[y] *P* value for differences among years
[x] Mean separation within columns by Tukey-Kramer adjustment for LS means in SAS MIXED procedure

Table 6. Least-squares means for laboratory samples of fruit from 'Royal Gala' apple on different rootstocks.[z]

Rootstock	Weight (g)	Diameter (cm)	Height (cm)	Height: diameter ratio	Firmness (kg·F)	Starch Starch index
B.9	203 b[w]	7.43 b	6.81 b	0.92 b	8.79 a	3.5 c
M.9	229 a	7.69 ab	7.22 a	0.94 ab	8.67 ab	3.8 c
SJM-15	222 ab	7.67 ab	7.11 a	0.93 ab	8.42 ab	3.5 c
SJM-189	222 ab	7.68 ab	7.14 a	0.93 ab	8.53 ab	4.1 bc
SJP84-5198	236 a	7.82 a	7.37 a	0.94 a	8.24 b	5.5 a
SJP84-5128	237 a	7.80 a	7.39 a	0.95 a	8.40 ab	4.6 b
P value[y]	0.0003	0.0016	< 0.0001	0.0039	0.0054	<0.0001
SJM-150[x]	254	8.09	7.48	0.93	7.98	4.2

[z] Average of 2012, 2014 and 2015
[y] *P* value for differences among rootstocks
[x] Not included in statistical analysis
[w] Mean separation within columns by Tukey-Kramer adjustment for LS means in SAS MIXED procedure

on M.9, and better than on B.9. SJM-189 and SJP84-5198 had the highest proportion of fruit with sufficient red color for the first color pick in some years; for SJM-189, the color improvement did not appear to be associated with any difference in internal fruit maturity. Although this trial was small due to limited available plant material, these early results are interesting enough to merit testing on a larger scale and in more locations, especially areas where M.9 is not sufficiently winter-hardy.

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