SJP84 Winter Hardy Dwarf Apple Rootstock Series from Agriculture and Agri-Food Canada National High Value Crop Breeding Program

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Apple production potential in Quebec is between 5.5 and 7 million bushels per annum. In 1986 and 1987, there were severe low temperature injuries, and yields were reduced to 2.8 million bushels and 4.0 million bushels, respectively. This loss represents approximately $18 million in 1986 and $12 million in 1987, and a concomitant increase in the volume of apples imported to the province. In 1993-1994, similar damage was reported by Quebec apple growers (Khanizadeh et al., 2000a). Cold winter temperatures is one of the most limiting factor in many apple-growing regions, especially in Northern Central Canada when the winter temperature dropped below –30°C (Granger, 1981; Asnong, 1982; Khanizadeh et al., 2000a).

Cold tolerance of many plant species has been extensively reviewed and studied (Chen and Li, 1980; Gusta et al., 1982; Li, 1987; Sakai and Larcher, 1987; Khanizadeh et al., 1989a; Khanizadeh et al., 1989b; Khanizadeh, 1991; Khanizadeh et al., 1992a; Khanizadeh et al., 1992b; Khanizadeh et al., 1994). Our previous studies have compared the concentration of amino acids, protein, sugars, starch, sorbitol, N, P, and K of cropped and non-cropped trees in relation to cold hardiness (Khanizadeh et al., 1989b; Khanizadeh et al., 1992a; Khanizadeh et al., 1994). It has been shown that cropped trees that progress into the winter with lower nutrient levels in their buds are more vulnerable to low temperatures than those on non-cropped trees (Khanizadeh et al., 1989b; 1992a).

There have been many studies of: 1) cold resistance and metabolic changes in apple woody tissue, (Brown, 1978; Li, 1987; Sakai and Larcher, 1987; Khanizadeh et al., 1989a; 1989b; 1992a; 1994), 2) types of freezing injury (Weiser, 1970; Granger, 1981); 3) breeding hardy varieties or using hardy intermediate frametocks (Stushnoff, 1972; Spangelo et al., 1974; Granger et al., 1991; 1992; 1993); 4) inactivating icenucleating bacteria (Lindow and Connell, 1984; Lindow et al., 1989); 5) use of chemical cryoprotectants (Ketchie and Murren, 1976); 6) cultural manipulation to slow growth and induce wood maturity in early autumn (Collins et al., 1978; Stang et al., 1978); and 7) autumn sprays of growth regulators to delay bud break. The use of winter hardy rootstocks and varieties, however, seems to be the most desirable approach to avoid winter injury and are used in international trials to screen this specific trait (Marini et al., 2001a; 2001b).

Many reports have been published on the winter hardiness and survival of selected rootstocks (Granger et al., 1993; Doroshenko et al., 1995; Skrivele et al., 1995; Fisher & Fisher, 1996; Yang et al., 1995; Witney, 1996; Khanizadeh et al., 2000a; Khanizadeh et al., 2000b; Marini et al., 2001a; Marini et al., 2001b; Webster, 2003). Alnarp 2 (A2) was reported to have the highest survival rate when exposed to low soil temperatures, followed by MM.104, Antonovka, M.26, MM.111, M.4, MM.106, M.9, and M.7, respectively (Zagaza, 1977). O.3 and O.8 were reported to be
hardier than M.26 and MM.106 (Heeney, 1981), and Bugadovsky was reported to be as hardy as M.26 (Czynczyk, 1979).

A part of the Agriculture and Agri-Food Canada (AAFC) National High Value Crop (NHVC) breeding program is devoted to development of adapted, dwarf and semidwarf, winter-hardy, and disease-resistant apple rootstocks. The original rootstock-breeding program began in early 1950 in Ottawa. Ottawa 3 (O.3) was the first commercially released clonal rootstock, released in 1974 from this National program, and the rest was sent to Quebec for further testing along with others developed in Ottawa and in Manitoba.

The identification of new, well adapted, winter-hardy, disease-resistant apple rootstocks that propagate easily will have a direct impact on the apple industry in the northern U.S. and in Canada by reducing production fluctuation caused by cold-temperature tree damage.

**Materials & Methods**

Several crosses were made in 1975 including *Malus robusta* R-5 with M.26 or with Budagovsky 579490, and also some seeds was collected from open pollinated O.3. Seeds were germinated under greenhouse conditions and planted in a nursery in 1980. Budding to Spartan was conducted in 1982, and trees with bud failure were cleft-grafted in 1983. All trees were planted in 1984 (5.5 x 3.0m) at the experimental farm of AAFC in Frelighsburg, Quebec. Standard orchard management practices were applied each year (Anon., 1976). Of the 908 trees started in 1984, only 499 were used for evaluation and the rest eliminated from the program due to their lack of winter hardiness, disease susceptibility, or other undesirable characters, like extreme difficulty to propagate in stool bed. Data are shown only for those nine superior rootstocks (Table 1) which have not shown any winter injury since 1984 and were not eliminated for other reasons.

Trunk circumference was measured at 25 cm above the graft union and used to calculate trunk cross-sectional area in 1990. Yield and incidence of root suckers were recorded annually from 1988-1990. Tree height and spread were measured as the maximum vertical extension of the tree and the maximum horizontal extension of the canopy, respectively (Table 1).

Two other sites were also established to examine the ease of propagation and suitability of the rootstocks for commercial grafting compare to M26, M9, and O.3 (data not shown).

‘Summerland McIntosh’ was used as scion for the nine superior rootstocks (Table 2). They were planted in four selected locations including L’Acadie (AAFC, Experimental site) and also tested under controlled conditions at two commercial grower sites Dunham and Mont St-Grégoire (Verger Dupuis Inc., 587 Hudon, Quebec).

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**Table 1. Performance of selected nine superior rootstocks with Spartan as the scion, selected from 908 seedlings planted in 1984 in Frelighsburg, Quebec.**

<table>
<thead>
<tr>
<th>Test Code</th>
<th>Selection</th>
<th>Parentage</th>
<th>TCA (cm²)</th>
<th>Cumulative Yield (kg)</th>
<th>YE (kg/cm²)</th>
<th>Canopy size 1990</th>
<th>Cumulative no of Root suckers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Height (m)</td>
<td>Spread (m)</td>
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<td>SJP84-5218</td>
<td>75-13-032</td>
<td>R5xM.26</td>
<td>13.2</td>
<td>22.95</td>
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<td>10.05</td>
<td>1.04</td>
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<td>1.25</td>
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<td>75-13-180</td>
<td>R5xM.26</td>
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</table>

1 TCA = trunk cross-sectional area.
2 YE = yield efficiency (cumulative yield/TCA).
Dunham, Qc., Canada; Verger Ivan Duchesne Inc., 118 ch. Sous-Bois, Mont St-Grégoire, Qc., Canada) in 1997 using three trees per sites/replicates. Several commercially grown cultivars (Gala, Spartan, McIntosh, Lobo) were also grafted onto these rootstocks to assess graft compatibility. During the multiplication and evaluation of the rootstocks, we discovered a clone of O.3 (O.3A) to be different from original O.3 developed earlier by Spangelo et. al. (1974). O.3A appears to produce wider branch angle and have a better rooting efficiency in stool beds compared to the original O.3. This rootstock (O.3A) was also tested along with advanced SJM rootstocks in all sites. M.27 was planted only at one commercial site due to the insufficient number rootstocks.

Results & Discussion

The majority of the superior rootstocks came from R.5 x M.26 crosses, and only one (75-13-065) came from R5 x B57490. The superior rootstocks showed no incompatibility with tested commercial scion cultivars. All rootstocks produced trees that were dwarf or semi-dwarf and were easier to propagate and numerically more efficient than trees on M.26 (Table 2).

Generally the trees were more vigorous in Dunham (Table 3) than in Mont St-Grégoire (Table 2) based on the trunk circumference. SJP84-5230, M.9, and M.27 were the least vigorous rootstocks in Dunham (Table 3) and Mont St-Grégoire (Table 2); however, there was not a significant difference between M.27, SJP84-5230, SJP84-5231, and M.9 in Mont St-Grégoire. MM.111 was the most vigorous at both sites.

SJP84-5218 and SJP84-5217 were the most precocious rootstocks at both sites. MM111 was the least precocious. In Dunham, SJP84-5198, SJP84-5189, SJP84-5162, and SJP84-5217 had higher cumulative yield than did M.26, SJP84-5231, MM.111, M.9, and SJP84-5230 (Table 3). In Mont St-Grégoire, SJP84-5218, SJP84-5217, SJP84-5174, SJP84-5180, O.3, and O.3A had higher cumulative yield than did MM.111

<table>
<thead>
<tr>
<th>Test code</th>
<th>Selection</th>
<th>Vigour</th>
<th>Circ. (mm)</th>
<th>TCA (cm²)</th>
<th>Height (m)</th>
<th>Spread (m)</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>1999-2002</th>
<th>Efficiency</th>
<th>No. of fruit</th>
<th>Fruit weight (g)</th>
<th>Burknort rating</th>
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<td>323</td>
<td>172</td>
<td>3.5</td>
<td>4.0</td>
</tr>
</tbody>
</table>

LSD 8

1 Vigour: Trunk circumference as a percent of M.9.
2 Trunk circumference and cross-sectional area (TCA) 25 cm above graft union.
4 Efficiency: (cumulative yield /TCA).
5 Fruit weight (g) was taken using 25 randomly selected fruits
6 Burknort rating: 0 = desirable, 10 = undesirable.
7 Average number of suckers counted during the 2002 season.
8 If difference between two means exceeds LSD, then it is significant at odds of 19:1.

Table 2. Performance of nine superior rootstocks and O.3A with Summerland McIntosh as the scion compared to M.26, M.9, M.26, MM.111 and O.3 planted in 1995 in Mont St-Grégoire, Verger Yvan Duchesne (average of 3 trees per replicate).
The most efficient rootstocks were SJP84-5198 in Dunham (Table 2) and SJP84-5218 in Mont St-Grégoire (Table 2). MM.111 resulted in the lowest efficiency at both sites. Few differences existed in burr knot rating (Tables 2 and 3) or root suckering (Table 2).

Based on the observation made since 1984 in six orchards, nine of the SJP84 series are being released for commercial testing and evaluation. All the retained SJP84 series are winter hardy, easier to propagate in stool bed than O.3, and produce a thick and vertical growing sucker in stool bed. No mildew, scab, or woolly aphid was observed on these rootstocks. To date, no graft incompatibility has been observed.

SJP84-5218 and SJP84-5198 stand out from the superior group, based on the visual tree observation (height, spread, branch angle, fruit distribution, tree form, graft union, root suckers, and burr knots) in five locations and also on their performance in stool beds.

A patent is pending for all of the SJP84 series rootstocks. A limited number of rootstocks are available for research purposes from the author (SK). Non-exclusive multiplication licences can be obtained from Agriculture and Agri-Food Canada. European nurseries can obtain a multiplication licence from Meiosis Ltd. (Bradbourne House, Stable Block, East Malling, Kent ME19 6DZ).

**Literature Cited**


Brown, G.N. 1978. Protein synthesis mechanisms relative to cold hardiness. *in Plant cold hardness*


