

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 framestocks (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 were 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,

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

Test Code	Selection	Parentage	TCA ¹ (cm ²)	Cumulative Yield (kg)	YE ² (kg/cm ²)	Canopy size 1990		Cumulative no of Root suckers
						Height (m)	Spread (m)	
SJP84-5218	75-13-032	R5xM.26	13.2	22.95	1.73	2.6	2.6	5.3
SJP84-5217	75-13-065	R5xB.57490	9.7	10.05	1.04	2.1	2.6	7.3
SJP84-5230	75-13-179	R5xM.26	23.0	28.65	1.25	2.9	2.5	0.0
SJP84-5198	75-13-180	R5xM.26	13.0	17.25	1.32	2.2	3.1	0.6
SJP84-5162	75-13-183	R5xM.26	14.2	25.5	1.81	2.9	2.4	13.0
SJP84-5231	75-13-209	R5xM.26	6.7	6.15	0.91	1.6	0.9	9.0
SJP84-5174	75-13-219	R5xM.26	18.9	20.70	1.10	3.4	3.5	7.0
SJP84-5189	75-13-246	R5xM.26	13.0	22.35	1.71	1.6	2.8	8.3
SJP84-5180	75-13-296	R5xM.26	17.7	19.8	1.12	2.9	2.6	6.3

¹ TCA = trunk cross-sectional area.

² YE = yield efficiency (cumulative yield/TCA).

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).

Test code	Selection	Vigour ¹	Circ. ² (mm)	TCA ² (cm ²)	Height (m)	Spread (m)	Yield (kg)				Efficiency ⁴ (kg/cm ²)	No. of fruit 1999-2002	Fruit weight ⁵ (g)	Burrknot rating ⁶	Suckers ⁷	
							1999	2000	2001	2002						
SJP84-5218	75-13-032	144	175	24	2.5	3.5	1.2	14.3	29.3	58.1	103.0	4.2	724	116	1.0	1.5
SJP84-5217	75-13-065	176	213	36	3.2	3.5	2.3	12.6	15.0	46.6	76.4	2.1	544	126	0.5	0.5
SJP84-5230	75-13-179	89	107	9	2.3	2.2	0.5	3.1	13.5	18.8	35.9	3.9	293	106	1.2	0.0
SJP84-5198	75-13-180	128	155	19	2.7	3.0	0.1	2.9	13.5	36.1	52.6	2.8	403	124	1.8	0.0
SJP84-5162	75-13-183	123	149	18	2.8	2.7	0.6	6.3	12.5	28.8	48.2	2.8	359	119	1.8	3.0
SJP84-5231	75-13-209	99	120	11	1.9	2.3	0.0	3.1	9.0	18.5	30.6	2.7	249	112	2.5	0.0
SJP84-5174	75-13-219	154	187	28	2.9	3.2	0.1	4.9	15.8	42.6	63.3	2.3	461	132	2.0	0.0
SJP84-5189	75-13-246	136	165	22	2.9	3.0	0.2	5.8	7.9	35.3	49.3	2.0	368	136	1.5	0.0
SJP84-5180	75-13-296	134	162	21	3.0	3.3	0.0	5.7	18.0	30.9	54.6	2.6	323	172	3.5	4.0
	O.3A	116	141	16	2.7	2.8	0.9	8.7	18.8	30.8	59.1	3.7	420	125	1.3	1.7
	M.26	151	183	27	3.3	3.2	0.6	3.9	12.1	32.1	48.6	1.8	292	163	3.0	0.0
	M.9	100	121	12	2.4	2.5	0.5	6.7	10.5	25.5	43.2	3.7	306	133	2.8	2.7
	MM.111	230	280	62	4.1	2.9	0.0	0.9	3.8	19.9	25.0	0.4	179	133	1.0	0.3
	M.27	79	96	7	1.9	2.1	0.2	3.2	6.8	9.2	19.4	2.6	136	133	1.5	0.0
	O.3	132	160	20	2.7	3.1	0.1	5.1	17.5	32.1	54.7	2.8	398	128	0.3	2.7
	LSD ⁸	28	34	10	54	84	1.2	5.4	8.8	19.8	29.0	1.1	207	30	1.9	3.8

¹ Vigour: Trunk circumference as a percent of M.9.

² Trunk circumference and cross-sectional area (TCA) 25 cm above graft union.

³ 1999-2002 = cumulative yield from 1999-2002.

⁴ Efficiency: (cumulative yield / TCA).

⁵ Fruit weight (g) was taken using 25 randomly selected fruits

⁶ Burrknot 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.

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 3. 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 Dunham, Verger Dupuis Inc. (average of 2-3 trees per replicates).

Test code	Selection	Vigour ¹	Circ. ² (mm)	TCA ² (cm ²)	Height (m)	Spread (m)	Yield (kg)					Efficiency ⁴ (kg/cm ²)	No. of fruit 1999-2002	Fruit weight ⁵ (g)	Burrknot rating ⁶
							1999	2000	2001	2002	1999-2002 ³				
SJP84-5218	75-13-032	173	150	18	1.9	2.4	2.3	8.9	5.2	15.2	31.8	1.8	263	118	3.8
SJP84-5217	75-13-065	172	149	18	1.9	2.3	2.7	9.0	4.0	18.1	33.8	1.9	279	114	2.2
SJP84-5230	75-13-179	108	93	7	1.4	1.3	0.8	3.9	0.8	4.0	9.4	1.5	78	126	1.5
SJP84-5198	75-13-180	153	132	14	2.1	2.3	4.0	10.1	5.5	17.1	36.7	2.6	294	114	2.5
SJP84-5162	75-13-183	169	146	17	1.7	2.7	3.3	8.7	7.5	14.4	33.8	2.0	260	118	3.5
SJP84-5231	75-13-209	122	105	9	1.7	1.3	3.2	4.7	2.9	9.2	20.1	2.1	171	126	2.8
SJP84-5174	75-13-219	205	177	25	1.9	2.2	0.5	7.7	9.3	15.4	33.0	1.3	296	96	1.0
SJP84-5189	75-13-246	182	157	20	2.8	2.8	2.1	7.4	6.6	19.9	36.0	1.9	319	100	1.8
SJP84-5180	75-13-296	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	O.3A	160	139	15	1.9	2.2	3.2	8.3	6.7	13.1	31.2	2.0	270	102	0.7
	M.26	173	149	18	1.8	2.7	1.6	5.7	2.4	12.6	22.2	1.3	185	119	3.3
	M.9	100	86	6	1.8	1.6	0.8	2.5	1.7	5.3	10.3	1.8	94	116	3.0
	MM.111	224	194	30	3.2	2.1	0.0	3.2	3.4	9.0	15.6	0.6	119	130	2.2
	O.3	156	135	15	1.9	2.7	1.9	7.5	8.1	11.8	29.2	2.1	242	104	1.7
	LSD ⁸	38	33	8	64	56	2.0	4.7	5.6	6.0	10.8	0.9	75	19	1.9

¹ Vigour: Trunk circumference as a percent of M.9.

² Trunk circumference and cross-sectional area (TCA) 25 cm above graft union.

³ 1999-2002 = cumulative yield from 1999-2002.

⁴ Efficiency: (cumulative yield / TCA).

⁵ Fruit weight (g) was taken using 25 randomly selected fruits

⁶ Burrknot 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.

and M.27 (Table 2).

The most efficient rootstocks were SJP84-5198 in Dunham (Table 3) and SJP84-5218 in Mont St-Grégoire (Table 2). MM.111 resulted in the lowest efficiency at both sites. Few differences existed in burrknot 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).

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