SJP84 Winter Hardy Dwarfing Apple Rootstocks from Agriculture and Agri-food Canada Breeding Program

Shahrokh Khanizadeh[1], Yvon Groleau[1], Raymond Granger[1], Gilles Rousselle[1] and Campbell Davidson[2]

[1]Agriculture and Agri-Food Canada, St-Jean-sur-Richelieu, QC, Canada

[2]Agriculture and Agri-Food Canada, Cereal Research Centre, Morden, MB, Canada

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 2.83 million bushels and 4.0 million bushels, respectively, in Quebec. This represents a loss of 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 temperature was always one of the most limiting factors in many apple-growing regions, especially in northern central Canada when the winter temperature dropped below -30°C (Khanizadeh et al., 2000a).

Cold tolerance of many plant species has been extensively reviewed and studied (Gusta et al., 1982; Khanizadeh et al., 1989). Our previous studies have compared the content of the amino acids, protein, sugars, starch, sorbitol, N, P and K of cropped and noncropped trees in relation to cold hardiness. It has been shown that cropped trees with lower nutrient levels in their buds are more vulnerable to low temperatures than those on noncropped trees (Khanizadeh et al., 1989, 1992).

There have been many studies including cold resistance and metabolic change in *Malus* woody tissue, types of freezing injury, breeding hardy varieties or using hardy intermediate framestocks, inactivating ice-nucleating bacteria, use of chemical cryoprotectants, cultural manipulation to slow growth and induce wood maturity in early autumn and autumn sprays of growth regulators to delay bud break. However, the use of winter hardy rootstocks and varieties seems to be the most important factor for avoiding winter injury.

Many reports have been published on the winter hardiness and survival of selected rootstocks (Khanizadeh et al., 2000a, 2000b; Marini et al., 2001a, 2001b). 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. Ottawa 3 (O.3) and Ottawa 8 (O.8) were reported to be hardier than M.26 and MM.106 and the rootstock Bugadovsky was reported to be as hardy as M.26.

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Part of the Agriculture and Agri-Food Canada (AAFC) National High Value Crop (NHVC) breeding program is devoted to development of adopted dwarf and semi-dwarf winter hardy, disease-resistant apple rootstocks. The original rootstock breeding program started 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 other developed rootstocks in HRDC and also those received from Morden, Manitoba.

The present aim of AAFC NHVC breeding program is to identify adapted winter hardy, disease-resistant apple rootstocks with ease of propagation compared to commercially used rootstocks.

This will have a direct impact on the apple industry in northern Canada by minimizing the level of tree damage and providing consistent apple production.

MATERIALS AND METHODS

Crosses were made in 1975 including *Malus robusta* R-5 x M.26 or *Malus robusta* R-5 x Budagovsky 579490. Seeds were also collected from open pollinated O.3. They were then allowed to germinate under greenhouse conditions and were planted in a nursery in 1980. Budding to Spartan was carried out in 1982 and trees with bud failure were cleft-grafted in 1983. All trees were planted in 1984 (5.5 x 3.0 m) at the experimental farm of AAFC, HRDC in Frelighsburg, Quebec. Standard orchard management practices were applied each year. Of the 908 trees started in 1984, only 499 were used for evaluation and the rest eliminated during the evaluation due to their lack of winter hardiness, disease susceptibility or other undesirable characteristics such as extreme difficulty to propagate in the stoolbed. Data are shown for only those nine superior rootstocks (Table 1) which did not show any degree of winter injury since 1984 or were not eliminated for other reasons including susceptibility to woolly apple aphid in the stoolbed. They were also tested for their ease of rooting and/or disease susceptibility.

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. Yield, fruit size and the most important characteristics were collected for only those rootstocks that also showed superior agronomic characteristics in the stoolbed during 1988-1990. Tree height and spread were measured, respectively, as the maximum vertical extension of the tree and the maximum horizontal extension of the canopy along the row (Table 1).

Two other parallel sites were also established to examine the ease of propagation and suitability of the rootstocks for commercial grafting. These sites included M.26, M.9 and O.3 (data not shown).

Summerland McIntosh was used as the scion for the most 9 winter hardy, easy to propagate and disease-resistant promising 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, Dunham, Qc., Canada; Verger Ivan Duchesne Inc., 118 ch. Sous-Bois, Mont St-Grégoire, Qc., Canada) in 1997 using 3 tree/site replicates. Several commercial cultivars (Gala, Spartan, McIntosh, Lobo) were also used as scions to evaluate 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 seems to produce wider branch angle and have better rooting efficiency in the stoolbed compared to O.3. This rootstock (O.3A) was also tested along with advanced SJM rootstocks in all sites. M.27 was planted at only one commercial site.

RESULTS AND DISCUSSION

Based on the data collected since 1980 none of the seedlings from open pollinated O.3 was retained. The majority of the retained rootstocks come from R5 x M.26 crosses and only one (75-13-065) was retained from R5 x B57490. All rootstocks were compatible with the cultivars tested. All rootstocks are either dwarf or semi-dwarf and were comparable to M.26 or M.9, had superior propagation characteristics and better efficiency than M.26 (Table 2). The circumferences of the trees in 2002 were compared to M.9 (M.9 equals 100) to estimate the vigor of the selected rootstocks before data analysis. Data are presented from only the first site used to select the rootstocks and the two other replicated commercial sites where we collected the detailed information. There was a significant interaction between the rootstocks and sites, which indicates there is a relationship between rootstock performance and soil type.

O.3A had similar vigor to O.3 but with better efficiency in one site (Table 2). This clone was reported to be more efficient and to improve the structure of the tree, especially the branch angle (wider) compared to conventional O.3 (personal communication, Dr. Raymond Granger, retired pomologist).

Generally the trees were more vigorous in Dunham (Table 3) compared to Mont St-Grégoire, the other commercially grown site (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), respectively. 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 in both sites.

Generally the trees were shorter in Dunham (sandy soil) compared to Mont St-Grégoire (sandy loam). SJP84-5218 and SJP84-5217 were the most precocious rootstocks based on the yield data in 1999 and 2000 in both sites. MM.111 was the least precocious. SJP84-5198, SJP84-5189, SJP84-5162 and SJP84-5217 had the highest total accumulative yield compared to M.26, SJP84-5231, MM.111, M.9 and SJP84-5230 (Table 3), however only SJP84-5218 and SJP84-5217 were significantly different from MM.111 and M.27 in the second site (Table 2). With the exception of SJP84-5231 and SJP84-5230, the accumulative yield of all other rootstocks was comparable to standard dwarf rootstocks. The most efficient rootstocks were SJP84-5198 in Dunham (Table 3) and SJP84-5218 and SJP84-5230 in Mont St.

TABLE 1

Performance of Spartan with 9 winter hardy and disease-resistant rootstocks selected from 908 seedlings planted in 1984 in Frelighsburg, Quebec.

Test code	Selection	Parentage	TCA[A] (cm^2)	Cumulative yield (kg)	YE[B] (kg/cm^2)	1990 Final Height (m)	1990 Final Spread (m)	Cumulative no. root suckers/tree
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

[A]TCA, trunk cross-sectional area.
[B]YE, yield efficiency=cumulative yield/TCA.

TABLE 2

Performance of McIntosh Summerland with 9 selected hardy rootstocks and O.3A in comparison with 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/replicate).

Test code	Selection	Vigor[1]	Circ.[2] (mm)	TCA[3] (cm^2)	Height (m)	Spread (m)	Yield (kg) 1999	2000	2001	2002	1999-2002[4]	Efficiency[5] (kg/cm^2)	Total no. of fruits[6] 1999-2002	Average fruit weight[7] (g)	Burr-knots[8]	Suckers[9]
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	28	34	10	54	84	1.2	5.4	8.8	19.8	29.0	1.1	207	30	1.9	3.8

[1]Vigor: Percent compared to M.9.
[2, 3]Circumference and tree cross-sectional area 25 cm above graft union.
[4]1999-2002 = cumulative yield from 1999-2002.
[5]Efficiency: cumulative yield/TCA.
[6]Total fruits number: fallen fruits + sampled and harvested.
[7]Average fruit weight (g) was taken using 25 randomly selected fruits.
[8]Burrknots: 0 = desirable, 10 = undesirable.
[9]Average number of suckers counted during the 2002 season.

Grégoire (Table 2). MM.111 and M.26 had the lowest efficiency in both sites. Some variability was observed for burrknot development but it was not very different from standard except for SJP84-5180 and SJP84-5218, which had the highest number of burrknots, but were not significantly different from M.26 and M.9 (Tables 2 and 3). The number of suckers was recorded at only one site (Table 2). No suckers were observed for M.26, M.27, SJP84-5198, SJP84-5189, SJP84-5231, SJP84-5174 and SJP84-5230. The highest number of root suckers was observed on SJP84-5180 but it was not significantly different from M.9, O.3 and MM.111.

Based on the observations 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 the stoolbed than O.3 and produce a thick and vertically growing sucker in the stoolbed. No sign of mildew, scab or woolly apple aphid susceptibility was observed on these series since 1984. The scion of several known cultivars grafted on these rootstocks (single tree) showed no sign of incompatibility since 1995.

SJP84-5218 and SJP84-5198 stand up better than others based on the visual tree observation (height, width, branch angle, fruit distribution, tree form and graft union, root suckers and burrknots) in 5 locations and also their performance in stoolbeds.

All these rootstocks are presently available for evaluation. However, they may exhibit a different dwarfing effect depending on the cultivars used as scion, soil structure and quality and other environmental factors.

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

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TABLE 3

Performance of McIntosh Summerland with 9 selected hardy rootstocks and O.3A in comparison with M.26 and M.9 planted in Dunham, Verger Dupuis Inc. (average of 2-3 trees /replicate).

Test code	Selection	Vigor[1]	Circ.[2] (mm)	TCA[3] (cm^2)	Height (m)	Spread (m)	Yield (kg) 1999	2000	2001	2002	1999-2002[4]	Efficiency[5] (kg/cm^2)	Total no. of fruits[6] 1999-2002	Average fruit weight[7] (g)	Burr-knots[8]
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	38	33	8	64	56	2.0	4.7	5.6	6.0	10.8	0.9	75	19	1.9

[1]Vigor: Percent compared to M.9.
[2, 3]Circumference and tree cross-sectional area 25 cm above graft union.
[4]1999-2002 = cumulative yield from 1999-2002.
[5]Efficiency: cumulative yield /TCA.
[6]Total fruits number: fallen fruits + sampled and harvested.
[7]Average fruit weight (g) was taken using 25 randomly selected fruits.
[8]Burrknots: 0 = desirable, 10 = undesirable.