

# Performance of Jonagold, McIntosh and Novaspy on three new semi-dwarf apple rootstocks in eastern Canada

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Cline, J. A., Norton, D., Embree, C. G. and Privé, J.-P. 2010. **Performance of Jonagold, McIntosh and Novaspy on three new semi-dwarf apple rootstocks in eastern Canada.** *Can. J. Plant Sci.* **90**: 877–883. Experiments were conducted in the provinces of Ontario (ON), New Brunswick (NB), and Nova Scotia (NS), all of which differ in growing regime, to determine the performance of Jonagold (Wilmuta strain), McIntosh and Novaspy on three new size-controlling apple [*Malus × domestica* (Borkh.)] rootstocks AR86-1-20, CG.008, and G.30 compared with a standard (M.26EMLA). For most response variables, rootstock performance differed in each location. Irrespective of cultivar, trees on AR86-1-20 were consistently more vigorous than those on M.26EMLA, while trees on G.30 were more vigorous in four of six experiments, and trees on CG.008 were similar to those on M.26EMLA in five of six experiments. G.30 and CG.008 were significantly more yield-efficient in four of the six experiments and show promise as replacements for rootstocks in this size category. CG.008 could be a good choice for a productive, well-anchored semi-dwarf rootstock between M.26EMLA and M.7 in vigour control, and CG.30 is likely a suitable replacement for M.7. The Horticulture Research International (HRI) rootstock AR86-1-20 is well adapted to wide soil and climate differences and may replace other rootstocks in the semi-dwarf vigour category. The results of this study provide a comprehensive look at comparable field performance of some new rootstocks for three of the five apple growing regions of Canada.

**Key words:** M.26EMLA, AR86-1-20, G.30, CG.008, *Malus*

Cline, J. A., Norton, D., Embree, C. G. et Privé, J.-P. 2010. **Performance de Jonagold, de McIntosh et de Novaspy sur trois nouveaux porte-greffes semi-nains de pommier dans l'est du Canada.** *Can. J. Plant Sci.* **90**: 877–883. Les auteurs ont entrepris des expériences en Ontario, au Nouveau-Brunswick et en Nouvelle-Écosse, provinces caractérisées par des conditions de croissance différentes, en vue de comparer la performance des greffons Jonagold (souche Decoster), McIntosh et Novaspy sur trois nouveaux porte-greffes de pommier (*Malus × domestica* [Borkh.]) à dimension limitée (AR86-1-20, CG.008 et G.30) et sur le porte-greffe standard M.26EMLA. La performance des porte-greffes diffère d'un lieu à l'autre pour la plupart des variables associées à la performance. AR86-1-20 donne toujours des pommiers plus vigoureux que ceux greffés à M.26EMLA, quel que soit le cultivar; les pommiers cultivés sur G.30 l'étaient également dans quatre cas sur six, tandis que ceux greffés à CG.008 présentaient une performance similaire à celle des pommiers cultivés sur M.26EMLA dans cinq expériences sur six. G.30 et CG.008 ont enregistré un rendement sensiblement plus élevé dans quatre expériences sur six et pourraient remplacer les porte-greffes actuels de cette taille. CG.008 pourrait s'avérer un bon choix comme porte-greffe semi-nain productif et bien ancré dont le contrôle de la vigueur se situerait entre M.26EMLA et M.7, alors que CG.30 pourrait remplacer le porte-greffe M.7. Le porte-greffe AR86-1-20 de l'Horticultural Research Institute est bien adapté à une multitude de sols et de climats et pourrait remplacer d'autres porte-greffes semi-nains. Les résultats de cette étude brossent un tableau comparatif général de la performance sur le terrain de quelques nouveaux porte-greffes dans trois des cinq régions du Canada où l'on se consacre à la pomiculture.

**Mots clés:** M.26EMLA, AR86-1-20, G.30, CG.008, *Malus*

Rootstocks are central to the design of modern fruit orchards. Not only do they influence profitability, rootstocks also influence tree vigour, yield, fruit size, tree mortality, and ease of management. Many apple rootstocks are commercially available, offering control of scion vigour and habit, precocious and consistent fruit yields, tolerance/resistance to soil or aerial borne pests and pathogens and unfavorable abiotic conditions (Webster 2003).

Currently all of the commercially important apple rootstocks in North America were developed in Europe and, therefore, none is ideally adapted to North American soils and environmental conditions. The East Malling Research Station in collaboration with Long Ashton (EMLA) in the United Kingdom released M.26EMLA, which is currently the most common semi-dwarfing rootstock planted in North America. Historically, many of the rootstocks that have been

available to apple producers interested in freestanding central-leader systems have low precocity and relatively low yield efficiency.

The Cornell-Geneva apple rootstock breeding program has released rootstocks (both G. and CG. series) in a wide variety of size control categories including semi-dwarfs, all reported to be highly productive and resistant to fire blight [*Erwinia amylovora* (Burrill 1882) Winslow et al. 1920] and collar rot [*Phytophthora cactorum* (L. & C.)] (Johnson et al. 2001). The Cornell-Geneva apple rootstock breeding program objectives are reported in detail elsewhere (Robinson et al. 1997). The AR series of rootstocks, which originate from Horticulture Research International (HRI), East Malling, are reportedly tolerant to apple replant disease and woolly apple aphid [*Erisoma lanigerum* (Hausm.)] and more resistant to *Phytophthora cactorum* than MM.106 and M.26 (Webster et al. 1986; Webster and Tobutt 2001; Webster 2003). One selection, AR86-1-20, derived from a cross between M.27 and MM.106, has performed well as a semi-dwarf rootstock in Great Britain and New Zealand (Webster 2003).

The objective of this experiment was to measure the performance of recent East Malling and Cornell-Geneva rootstocks in comparison with the industry standard, M.26EMLA, utilizing several locations, three cultivars, and uniform plantings.

#### MATERIALS AND METHODS

Five apple [*Malus × domestica* (Borkh)] rootstocks were micro-propagated by tissue culture at the Atlantic Food and Horticulture Research Centre (AFHRC), Kentville, Nova Scotia. The sources of the mother plants were derived from rootstock suckers from the 1984 NC-140 experiment (NC-140 1996) and included: M.26EMLA, previously imported as M.26EMLA rootstock liners from Treco (Oregon, USA); M.26 (NS), a sub-clone or variant of M.26EMLA; G.30 (a 1974 cross of *Malus robusta* 5 × M.9); and CG.008 (a cross of Ottawa 3 × *Malus robusta* 5). AR86-1-20 was cultured from rootstock liners imported from Horticultural Research International, East Malling (Webster and Tobutt 2001; Webster 2003). The M.26 (NS) rootstock was selected from a root sucker from a single tree which exhibited high yield performance and remained free-standing for over 10 yr in the 1984 NC-140 rootstock experiment (C. Embree, personal communication). To ensure uniformity of plant material, all rootstocks were propagated and grown in a research nursery at the AFHRC, Kentville, NS, and distributed in a dormant state as finished trees to the planting sites in New Brunswick and Ontario in the spring of 1999.

#### Location 1 – Simcoe, Ontario

An 8-yr apple rootstock experiment was initiated in 1999 at the University of Guelph, Simcoe Campus, Ontario (lat. 42°51'40"N, long. 80°16'8"W) with the scion cultivars Jonagold (Wilmuta strain) and Novaspy

grafted on the following rootstocks: M.26EMLA, AR 86-1-20, G.30 and CG.008. Cultivars were planted as 1-yr-old whips and in separate rows at spacings of 3 m × 4.4 m (754 trees ha<sup>-1</sup>) and within each row, rootstocks were arranged in a randomized complete block design (RCBD) with seven replications. Trees were trained as slender spindles with a 2 m wooden support post adjacent to each tree and were trickle-irrigated with approximately 25 mm of water weekly during the growing season using 2 L h<sup>-1</sup> emitters spaced 60 cm apart within the row. Fruit were hand thinned annually approximately 30–45 d after full bloom after “June” drop to single fruitlets and spaced approximately 15 cm apart. Standard cultural and pest management practices for Ontario were used (Ontario Ministry of Agriculture, Food and Rural Affairs 2008). This site, which was previous planted to apple in 1997, was kept fallow in 1998 and in the autumn prior to planting, 40 t ha<sup>-1</sup> of poultry manure was incorporated into the soil to help overcome any potential soil replant disease issues (Stirling et al. 1995). The orchard soil was classified as a Brady sandy loam (Aquaic Hapludalf) with imperfect drainage and soil textures consisting of mainly lacustrine sand and sandy loam over glaciolacustrine clays.

#### Location 2 – Kentville, Nova Scotia

An 8-yr apple rootstock experiment was initiated in 1999 at the Atlantic Food and Horticulture Research Centre (AFHRC), Kentville, Nova Scotia (lat. 45°7'57"N, long. 64°26'8"W) with the scion cultivars Jonagold (Wilmuta strain), McIntosh (Blackmac VI strain) and Novaspy grafted on the following rootstocks: M.26EMLA, M.26 (NS), AR 86-1-20, G.30, and CG.008. Cultivars were planted as 1-yr-old whips in separate rows at a spacing of 5 m × 1.75 m (1 143 trees ha<sup>-1</sup>) and within each row, rootstocks were arranged in a RCBD with seven replications. Trees were not hand-thinned or irrigated and were trained using a free-standing central leader system. Standard cultural and pest management practices for Nova Scotia were used (Craig 2003).

#### Location 3 – Bouctouche, New Brunswick

An 8-yr apple rootstock experiment was initiated in 1999 at the Senator Hervé J. Michaud Research Farm, Agriculture and Agri-Food Canada Research Station at Bouctouche, New Brunswick (lat. 46°28'30"N, long. 64°43'29"W) with the scion cultivar Novaspy grafted on the following rootstocks: M.26EMLA, AR 86-1-20, G.30, and CG.008. Trees were planted as 1-yr-old whips in separate rows at a spacing of 2.5 m × 4.5 m (889 trees ha<sup>-1</sup>) and within each row rootstocks were arranged in a RCBD with seven replications. Prior to planting, 500 kg ha<sup>-1</sup> of 10N-10P-10K fertilizer was applied by broadcasting over the whole plot. Subsequently, trees were treated by annually broadcasting 15.5N-0P-0K fertilizer within the tree row at a rate of 60 g tree<sup>-1</sup> in the first year and gradually increasing this

to 300 g tree<sup>-1</sup> in the final year (split application). Trees were trickle-irrigated with approximately 25 mm of water weekly (in the absence of rain) during the growing season using 4 L h<sup>-1</sup> emitters spaced 60 cm apart, and trained as vertical axes with individual support posts adjacent to each tree. In 2004, fruit were hand thinned to single fruits spaced approximately 15 cm apart, and in subsequent years trees were chemically thinned when fruitlets were approximately 10–15 mm in diameter using 2 L ha<sup>-1</sup> Sevin XLR Plus (Bayer CropScience Inc., Calgary, AB) and a commercial airblast sprayer. Follow-up hand-thinning was completed 30–45 d after full bloom to ensure fruitlets were spaced approximately 15 cm apart. Standard cultural and pest management practices for New Brunswick were used (Craig 2003).

### Horticultural and Statistical Measurements

Across all locations, trees were planted with the bud union approximately 10 cm above the soil line. Trunk circumference was measured at the end of each growing season at 30 cm above the soil line. All fruit were harvested at their commercial harvest dates for each region and the weight and number of fruit per tree recorded to determine mean fruit size and crop density (number of fruit per unit trunk cross-sectional area). Individual cultivars from each experiment were subjected to analysis of variance using SAS PROC MIXED procedure (SAS Institute, Inc., Cary, NC) based on a RCBD. The model considered replication a random effect because of the potential for missing plots (trees) over time because of mortality (Marini et al. 2008). Data sets from each cultivar and within each location were analyzed separately because of significant location × rootstock interaction for a given cultivar, likely due to confounding effects between cultivars and sites (growing conditions, etc.). Percent tree mortality data were transformed using the arc sin function; however, treatment differences were similar between transformed and untransformed values and, therefore, means are presented untransformed. Analysis of covariance using crop load as a covariate was performed on mean fruit weight to evaluate rootstock effects on mean fruit weight at harvest independent of crop load (Marini et al. 2002). Means were separated using Tukey's HSD ( $P = 0.05$ ).

## RESULTS AND DISCUSSION

### Tree Survival

After eight growing seasons, no significant differences in tree mortality among rootstocks were observed at any of the three sites for Jonagold (Table 1), Novaspy (Table 2), or McIntosh (Table 3). Numerically, mortality was greatest among Novaspy in Ontario, but because of high variability no significant statistical differences were observed. Tree mortality in one instance was associated with winter injury symptoms followed by secondary disease infection. In another instance, mechanical injury

**Table 1. Tree mortality, growth and yield of Jonagold on several dwarfing rootstocks, 1999–2006**

Rootstock	Tree mortality (%)	TCSA (fall 2006) <sup>z</sup>		Cumulative yield (2000–2006) (kg tree <sup>-1</sup> )	Cumulative yield efficiency (kg cm <sup>-2</sup> )
		(cm <sup>2</sup> )	% of M.26		
<i>Nova Scotia</i>					
AR86-1-20	0	45.6a	241	73a	2.08
CG.008	0	34.1b	180	96a	2.71
CG.30	0	44.5a	235	107a	2.34
M.26EMLA	0	18.9c	100	48b	2.44
M.26 (NS)	14	20.1c	106	45b	2.31
Significance	NS	***		***	NS
<i>P</i> value	0.4269	<0.0001		<0.0001	0.3527
<i>Ontario</i>					
AR86-1-20	0	119.0a	212	129ab	1.12b
CG.008	0	67.1bc	119	151a	2.26a
CG.30	14	78.2b	139	154a	1.98a
M.26EMLA	0	56.3c	100	108b	2.12a
Significance	NS	***		*	***
<i>P</i> value	0.4155	<0.0001		0.0203	0.0009

<sup>z</sup>Values with the same letter within a given column are not significantly different according to Tukey's HSD multiple range test at  $P = 0.05$ . \*, \*\*, \*\*\* Significant differences at  $P = 0.05$ ,  $P = 0.10$ , and  $P = 0.01$ , respectively; NS, not significant.

from orchard equipment appeared to be the cause of mortality.

### Tree Size

With the exception of Novaspy in Ontario, significant rootstock differences in tree size based on trunk cross-sectional area after 8 yr were observed among all cultivars and at all locations. In all locations except New Brunswick and Jonagold in NS, trees on AR86-1-20 rootstock were significantly larger than trees on any of the other rootstocks. In Nova Scotia, Jonagold trees on AR86-1-20 and G.30 were 135–140% larger ( $P < 0.0001$ ) than M.26EMLA, while trees on CG.008 were intermediate in size (80% larger than M.26EMLA) (Table 1). Jonagold trees on tissue-cultured M.26 (NS) were similar in size to the standard stoolbed-produced M.26EMLA. In Ontario, Jonagold trees on AR86-1-20 were 212% larger ( $P < 0.0001$ ) than M.26EMLA. Trees on G.30 were intermediate in size (139% larger than M.26EMLA), while those on CG.008 were similar in size to M.26EMLA.

Growth of Novaspy trees differed among rootstocks and between locations (Table 2). The largest Novaspy trees were observed on AR86-1-20 rootstocks in NS and ON; however, in NB the largest Novaspy trees were observed on G.30. In all locations, Novaspy trees on CG.008 were similar in size to M.26EMLA rootstock. In Nova Scotia, McIntosh trees on AR86-1-20 were 208% of the size of M.26EMLA, whereas trees on CG.008 and G.30 were similar in size to M.26EMLA (Table 3).

**Table 2. Tree mortality, growth and yield of Novaspy on several dwarfing rootstocks, 1999–2006**

Rootstock	Tree mortality (%)	TCSA (fall 2006) <sup>z</sup>		Cumulative yield (2000–2006) (kg tree <sup>-1</sup> )	Cumulative yield efficiency (kg cm <sup>-2</sup> )
		(cm <sup>2</sup> )	% of M.26		
<i>New Brunswick</i>					
AR86-1-20	0	46.7a	137	24b	0.51
CG.008	0	35.6b	104	69a	1.97
CG.30	14	52.4a	153	81a	1.55
M.26	0	34.2b	100	31b	0.91
Significance	–	***		***	***
P value	0.416	0.0003		<0.0001	<0.0001
<i>Nova Scotia</i>					
AR86-1-20	0	60.7a	233	161a	2.50
CG.008	0	34.3b	131	112ab	3.27
CG.30	0	30.6bc	117	139a	4.33
M.26	0	26.1c	100	63b	2.58
M.26 (NS)	14	23.4bc	90	60b	2.64
Significance	NS	***		***	***
P value	0.5199	<0.0001		0.0002	0.0002
<i>Ontario</i>					
AR86-1-20	0	97.2	134	59c	0.49
CG.008	43	69.0	95	94ab	1.72
CG.30	29	68.3	94	103a	1.65
M.26EMLA	29	72.7	100	60bc	0.97
Significance	NS	NS		***	**
LSD (P=0.05)	42	34.9		30.59	0.676
P value	0.2282	0.2069		0.0009	0.0035

<sup>z</sup>Values with the same letter within a given column are not significantly different according to Tukey's HSD multiple range test at  $P = 0.05$ . \*, \*\*, \*\*\* Significant differences at  $P = 0.05$ ,  $P = 0.10$ , and  $P = 0.01$ , respectively; NS, not significant.

### Yield

Significant rootstock differences in annual (data not shown) and cumulative yields were observed for each cultivar and location (Figs. 1–3). Cumulative yields (2001–2006) of Jonagold were greatest for G.30 and CG.008 rootstocks, intermediate for AR86-1-20, and lowest for both M.26 strains in NS (Fig. 1A) and M.26EMLA in ON (Fig. 1B). G.30 and CG.008 produced higher yields beginning in year 3 in NS and year 6 in Ontario, indicating the ability of these rootstocks to bear earlier than M.26EMLA. By year 8 (2006) in NS, the cumulative yields of G.30 and CG.008 were 137 and 114% of M.26, respectively. In ON over the same period (Fig. 1B), the performance of the same rootstocks was 43 and 40% greater than M.26EMLA. In NS, after year 6 (2004), annual yields of AR86-1-20 began to surpass the other rootstocks leading to cumulative yields in year 8 comparable with G.30 and CG.008. No differences in annual (data not shown) or cumulative yields among M.26EMLA and M.26 (NS) rootstocks were observed over the study period (Fig. 1A).

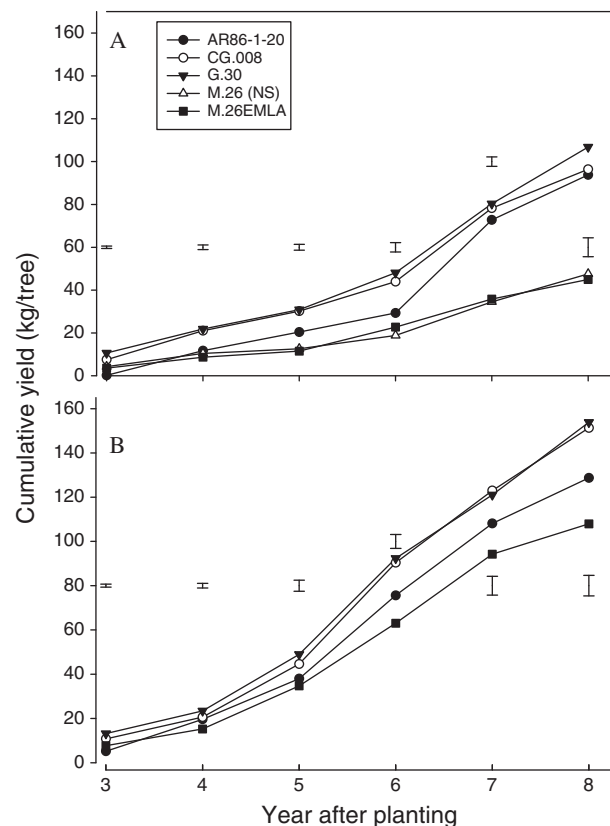
Cumulative yields from Novaspy trees were influenced markedly by rootstock (Fig. 2). In NS (Fig. 2A) after 6 yr

**Table 3. Tree mortality, growth and yield of McIntosh on several dwarfing rootstocks, 1999–2006**

Rootstock <sup>z</sup>	Tree mortality (%)	TCSA (fall 2006) <sup>z</sup>		Cumulative yield (2000–2006) (kg tree <sup>-1</sup> )	Cumulative yield efficiency (kg cm <sup>-2</sup> )
		(cm <sup>2</sup> )	% of M.26		
<i>Nova Scotia</i>					
AR86-1-20	0	60.2	208	114	1.91
CG.008	0	34.2	118	117	3.49
CG.30	0	38.2	132	110	2.89
M.26EMLA	14	29.0	100	55	1.91
Significance	NS	***		***	***
P value	0.4155	<0.0001		<0.0001	<0.0001

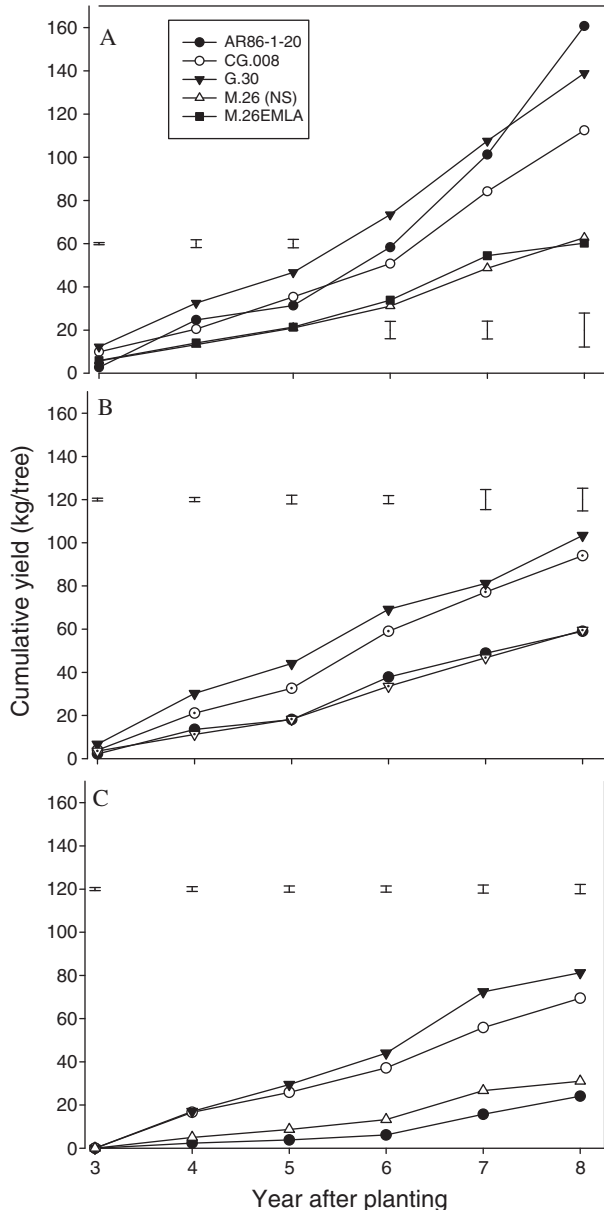
<sup>z</sup>Values with the same letter within a given column are not significantly different according to Tukey's HSD multiple range test at  $P = 0.05$ . \*, \*\*, \*\*\* Significant differences at  $P = 0.05$ ,  $P = 0.10$ , and  $P = 0.01$ , respectively; NS, not significant.

of bearing, trees on AR86-1-20, followed by G.30 and CG.008, produced 167, 131, and 87% greater cumulative yields, respectively, than M.26(NS). As was observed with Jonagold, no differences in annual or cumulative yields among M.26EMLA and M.26 (NS) rootstocks



**Fig. 1.** Cumulative yield of Jonagold apples in response to several size-controlling rootstocks grown in Nova Scotia (A) and Ontario (B). Error bars represent the standard error of the means.

were observed over the study period (Fig. 2A). Cumulative yields of Novaspy in ON, which were generally less than in NS, were greatest from trees on G.30 and CG.008 rootstocks, both of which were significantly greater than AR86-1-20 and M.26EMLA (Fig. 2B). The increase in yield over time was consistent between years, and as a result G.30 was the most productive rootstock during the study period. By 2006, cumulative yields of G.30 and CG.008 were 74 and 58% greater, respectively, than M.26EMLA. In NB, cumulative yield of Novaspy was



**Fig. 2.** Cumulative yield of Novaspy apples in response to several size-controlling rootstocks grown in Nova Scotia (A), Ontario (B) and New Brunswick (C). Error bars represents the standard error of means.

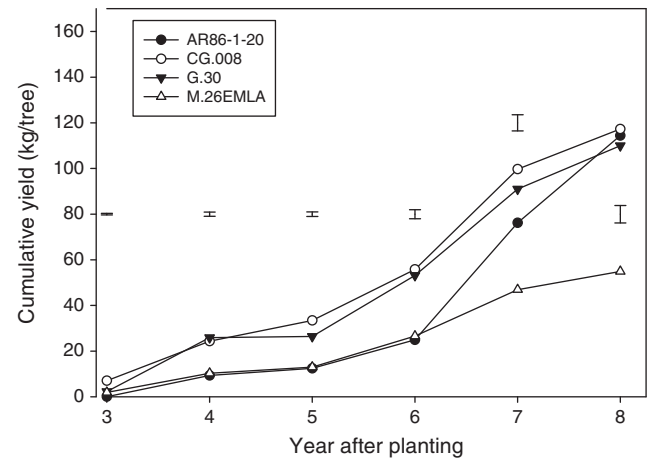
significantly greater for trees on G.30 and CG.008 rootstocks in comparison with M.26EMLA (Fig. 2C). Cumulative yields from AR86-1-20 were lowest among those tested. Again, G.30 and CG.008 were significantly more precocious than M.26EMLA.

Cumulative yields of the cultivar McIntosh were greatest on G.30, and by year 8, CG.008 and AR86-1-20 were nearly twice as productive as M.26EMLA (Fig. 3). CG.008 and G.30 rootstocks were significantly more precocious after year 4, while AR86-1-20 began to bear significantly more fruit than all the other rootstocks after year 6 (2004). This coincided with greater tree growth from McIntosh trees on AR86-1-20 rootstock (data not shown).

Effects of rootstock on fruit weight were often nonsignificant among years and, when statistically significant, were modest and often inconsistent for a given cultivar. When covariate analyses was conducted using the number of fruit per unit trunk cross-sectional area as a covariate, rootstock effects were even less significant, indicating fruit size was influenced more by crop load than rootstock (data not shown).

#### Yield Efficiency

Significant rootstock differences in cumulative yield efficiency, i.e., a measure of cumulative yield, which is corrected for tree size, were observed for all cultivars and locations except Jonagold in NS (Tables 1–3). For Jonagold in ON, M.26EMLA, M.26NS, CG.008 and G.30 were equally efficient rootstocks, while AR86-1-20 was significantly less efficient by approximately 50% (Table 1). For Novaspy, CG.008 followed by G.30 were the most efficient rootstocks in NB, while G.30 was the most efficient rootstock in NS, and CG.008 and G.30 were among the most efficient rootstocks in ON (Table 2). In NS and ON, M.26EMLA and AR86-1-20 were similarly efficient, whereas in NB, AR86-1-20 had



**Fig. 3.** Cumulative yield of McIntosh apples in response to several size-controlling rootstocks grown in Nova Scotia. Error bars represent the standard error of the means.

significantly lower cumulative yield efficiency than the other rootstocks. No significant difference in yield efficiency was observed between M.26EMLA and M.26 (NS) rootstocks for either Jonagold or Novaspy scions. For McIntosh, CG.008 followed by G.30 were the most efficient rootstocks and M.26EMLA and AR86-1-20 had similar, but significantly lower cumulative yield efficiencies.

### DISCUSSION AND SUMMARY

Positive performance of the Cornell-Geneva rootstocks, and G.30 specifically, have been reported in North America (Robinson et al. 1997, 2002, 2003; Robinson 2003; Robinson and Hoying 2004; Marini et al. 2000, 2006), New Zealand (White and Tustin 2000) and South Africa (Costa and Stassen 2008; Costa 2009). Based on experiments in New York, Robinson et al. (1997) indicate that G.30 is a semi-dwarfing rootstock with vigour control between that of M.26EMLA and M.7. However, vigour of G.30 was closer to that of M.26 EMLA at the conclusion of a 10-yr experiment with Gala (Marini 2006) and approximately 44% more vigorous than M.26EMLA with McIntosh as a scion (Autio et al. 2007). In other studies, yields of McIntosh grown across 10 locations in North America were greatest on G.30 rootstocks and lowest on M.26EMLA (Autio et al. 2007). This is consistent with other studies, where G.30 has demonstrated greater cumulative yields than M.7, and has displayed both fire blight resistance and cold hardiness (Robinson and Hoying 2004). In addition, G.30 has been shown to be tolerant of specific apple replant disease (Isutsa and Merwin 2000; White and Tustin, 2000). The precocity of G.30 may be its biggest advantage over other semi-dwarfing rootstocks such as M.7 and M.26EMLA, inducing early bearing the third year after planting. In some situations, G.30 has displayed graft union brittleness when grafted with Gala and, therefore, tree support is recommended with this specific scion/rootstock combination (Robinson et al. 2003; Robinson and Hoying 2004). In the present study, no weak unions or breakage was observed on G.30 for the scions evaluated. Concurrently, the data in the present study are consistent with those reported in the literature indicating that G.30 is a very productive semi-dwarf rootstock that is very resistant to fire blight, tolerant of replant disease, has a wide climate and soil adaptability and proven field winter hardiness to  $-35^{\circ}\text{C}$  (Robinson and Hoying 2004). It would appear to favour Northern climates with short growing seasons, as it generally performed better in NB and NS than ON.

The rootstock CG.008 was developed at the New York State Agricultural Experiment Station in Geneva by Dr. Jim Cummins. It was included in a 1989 rootstock experiment at AFHRC, Kentville, NS. Dr. Cummins designed this trial with McIntosh as the cultivar to assess tree performance in a northern climate. Trees on CG.008 were productive and appeared to be similar to the size of M.26EMLA in adjacent blocks. Upon examination by

Dr. Cummins, trees were considered to be very well anchored (C. Embree, personal communication). Unfortunately, CG.008 has not been commercialized and it would appear that Cornell University has no plans to do so (Robinson and Hoying 2004).

In New Zealand after five seasons, Gala trees on AR86-1-20 produced trees of comparable in size to those on MM.106 with significantly higher cumulative yields, but AR86-1-20 was less yield efficient (White and Tustin 2000). It was also observed in the same study that MM.106 was more tolerant to replant soil than AR86-1-20 and other AR selections under evaluation. In the United Kingdom, trees on AR86-1-20 rootstock have been slightly less vigorous than trees on MM.106, but with comparable yields and fruit size as MM.106 (Webster and Tobutt 2001). In the present study, fruit size was similar between M.26EMLA, M.26NS and AR86-1-20, and in one of the three experiments, was very productive after year 8. Low precocity is, however, a primary limitation of this rootstock, particularly if utilized in more intensive orchard systems relying on early fruit yields for profitability.

The results presented provide a fairly comprehensive look at comparable field performance for three of the five apple-growing regions of Canada. Newly introduced semi-dwarf apple rootstocks from the Cornell-Geneva and Horticultural Research International (HRI) rootstock breeding programs are compared with the traditional M.26EMLA. Utilizing these data, these rootstocks can all be categorized in a class larger than M.26EMLA. Even so, the G.30 and CG.008 were significantly more yield-efficient in four of the six experiments and show promise as replacements for rootstocks in this size category especially in areas with high fire blight pressure. While the HRI introduction is more vigorous and less efficient, it performed well and should be compared with MM.106. The site  $\times$  rootstock interaction points out the need for more research on the influence of rootstock or cultivar and its potential dependence on the apple-growing conditions in which it is grown. In summary CG.008 could be an ideal choice for a productive, well-anchored semi-dwarf rootstock marginally larger than M.26EMLA. G.30 is likely a good replacement for M.7 as it is very productive and significantly more vigorous than M.26EMLA.

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