APPLE ROOTSTOCK VIGOUR AND PRODUCTION

EFFECTS OF ROOTSTOCKS ON HONEYCRISP

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Apple Rootstock Vigour and Production: Effects of Rootstocks on Honeycrisp

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Semi-dwarfing and dwarfing rootstocks are used in apple horticulture to control scion vigor and increase yield efficiency (Warschefsky et al. 2016). Some rootstocks can also confer apple trees with hardiness and resilience against biotic pressures. A suitable rootstock should be compatible with the scion cultivar of interest, the local microclimatic and soil conditions, as well as the planting spacing. Selecting the right rootstock to start with can save growers time and cost on orchard management, particularly for horticulturally challenging cultivars such as Honeycrisp apple (*Malus domestica* var. Honeycrisp).

Since its release in 1991, Honeycrisp has become one of the most sought-after apples. Its juiciness, firmness, crispiness, and well balanced sweetness and tartness, makes it desirable to consumers (Luby and Bedford 1992). However, growers have to deal with some of its undesirable pre- and post-harvest traits, such as severe leaf chlorosis and strong biennial bearing (Telias et al. 2006, Embree et al. 2007, Serra et al. 2016). Crop load, nutrient, and water must be carefully managed in order to prevent the dramatic variations in fruit size, and the development of physiological disorders such as bitter pit and soft scald at harvest and after storage (Biggs and Peck 2015). Proper rootstock selection has been a preferred approach to both reduce the demand in orchard management and sustain fruit strong production (Robinson et al. 2011).

Photo 1. NC140 2010 Honeycrisp rootstock trial in Summerland Research and Development Centre. **(A-1)** Field overview at establishment in the spring of 2010. **(A-2)** Tree training at initial planting. **(B)** Row view in September 2018. **(C)** Field overview in April 2021.

NC-140 Regional Rootstock Research Project aims to improve economic and environmental sustainability in tree fruit production through changes in rootstock use (www.nc140.org). Since 2010, participating researchers at the Summerland Research and Development Centre (Agriculture and Agri-Food Canada) have been evaluating the performance of Honeycrisp apple on a variety of rootstocks in sandy loamy soil under the typical Okanagan semi-arid climatic conditions (Photo 1). The trees are trained to tall spindle axes and spaced at 4 X 12 feet apart (1.2 X 3.7 m), with trunks supported by both bamboo and 4-wire vertical trellis system. Winter pruning is usually conducted in February - March. Crop load is managed by chemical blossom thinning, and chemical and hand thinning on fruitlets. Water and nutrients are supplied through drip irrigation and fertigation. Overhead irrigation is applied in July and August to provide canopy cooling. Commonly observed horticultural challenges are excessive root suckers, leaf chlorosis, biennial bearing, large variations in fruit size, and high incidence of bitter pit and soft scald after air storage (Photo 2).

Photo 2. Horticultural challenges of Honeycrisp scion noticed in NC140 2010 Summerland rootstock trial. **(A-1)** Canopy zonal chlorosis; **(A-2)** Leaf chlorosis; **(B)** Variation in fruit size under heavy crop load; **(C)** Moderate to severe soft scald after 3-month air storage.

This document presents the performance of Honeycrisp on 16 rootstocks in the 9th year of the trial, including 3 industrial standard Malling rootstocks, 4 Budagovsky rootstocks and 9 Geneva rootstocks. According to the scion vigor from large to small, these rootstocks are classified into semi-dwarfing (B.64-194, B.7-20-21, G.4004, G.202N and G.3001), large dwarfing (G.214, G.4814, G.41N, G.935N, M.26EMLA and M.9Pajam2), moderate dwarfing (B.10, G.11 and M.9T337), and small dwarfing (B.9 and G.4003) (Autio et al. 2020) (Fig. 1, Table 1).

Photo 3. Typical grafted union characteristics of Honeycrisp scion with the rootstocks representing different vigor classes in the spring of 2021: Semi-dwarfing B.64 -194 and G.4004; Large dwarfing G.41N, G.935 and M.26EMLA; Moderate dwarfing B.10, G.11 and M.9T337; and, Small dwarfing B.9. Scale bar = 30 cm

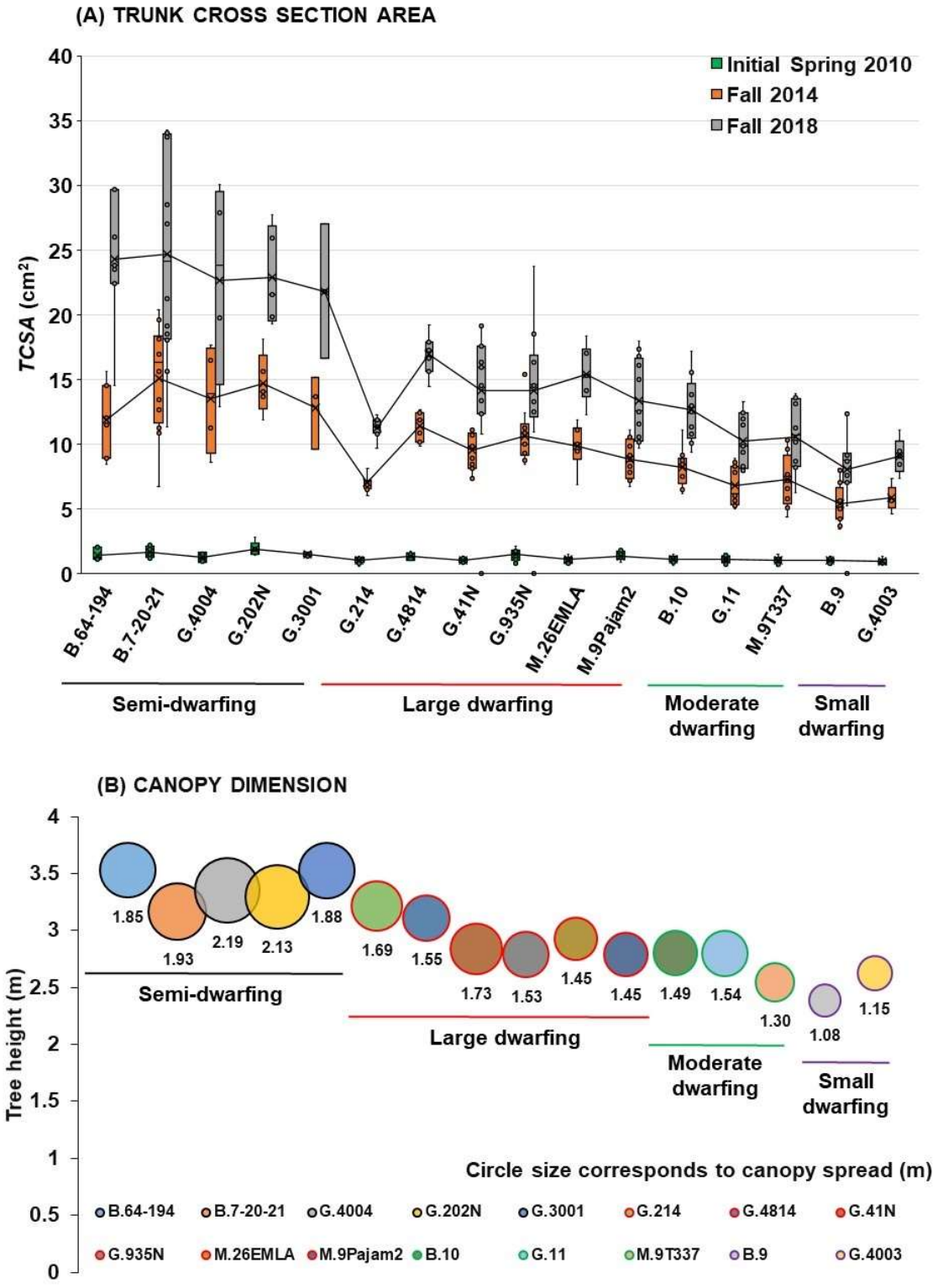

Fig. 1 Trunk cross section area (TCSA) in 2010, 2014 and 2018 **(A)**, and canopy dimension in 2017 **(B)**, of Honeycrisp apple on 16 rootstocks in the NC140 2010 trial in Summerland, British Columbia, Canada.

All the rootstocks started fruit bearing at the 2nd – 3rd leaf. The higher the yield of the rootstock-scion combination, the stronger their biennial bearing tended to be. Higher crop load in general led to decreases in fruit size. Trunk cross section area (*TCSA*) (Fig. 1A), tree height, and canopy width in the fall of 2018 (Fig. 1B), the number of suckers and zonal chlorosis (Table 1), cumulative yield (Fig. 2A), and cumulative yield efficiency in 2014-2018 (Fig. 2B) (Table 1), were analyzed for each rootstock. The typical grafted union characteristics of featured rootstocks are shown in Photo 3. In addition, features of resilience and tolerance of 13 rootstocks were retrieved from the studies done elsewhere in North America (Table 2). The most noticeable advantages and disadvantages of the evaluated rootstocks are summarized as below.

- In general, the semi-dwarfing rootstocks produced larger scion *TCSA* (Fig. 1A) and larger canopy (Fig. 1B) than the dwarfing rootstocks. Amongst the dwarfing rootstocks, large dwarfing had larger scion *TCSA* than moderate and small dwarfing, except for G.214 which *TCSA* was smaller than expected.
- G.202N, G.935N, G.214 and G.4814 produced excessive root suckers (Table 1, shown in orange).
- G.3001, G.214, G.935N, G.4814, G.11 and G.4003 were more susceptible to leaf chlorosis (Table 1, zonal chlorosis ≥ 0.5). Better nutrition and crop load management would help to alleviate this issue.
- In general, the rootstocks with strong vigor had higher cumulative yield (Fig. 2A) but lower yield efficiency (Fig. 2B) (Table 1). In the projected five-year yield of 2200 trees per hectare at 1.2 m × 3.7 m spacing, all the semi-dwarfing rootstocks, the large dwarfing except M.9Pajam2, and the moderate dwarfing B.10, exceeded the standard M.9T337. The top four in projected ton of fruits per hectare were G.202N, G.4004, G.4814 and G.935N (Table 1).
- When selecting the most suitable rootstock, one should choose from the appropriate vigor class in accordance to the actual planting density, and avoid excessive root suckers and severe chlorosis. It is critical to take yield, yield efficiency and other important resilience characteristics into consideration.
    - In the semi-dwarfing category, G.4004 led to high cumulative yield and did not show any undesirable traits.
    - In the large and moderate dwarfing categories:
        - G.41N led to higher cumulated yield than the standard M.9T337, and did not show undesirable traits. It did not develop brittle grafted union in this trial, probably attributed to the trellis-bamboo supporting system.
        - G.214 showed the highest cumulative yield efficiency; however, the small *TCSA*, large amount of root suckers and severe leaf chlorosis indicated its incompatibility with Honeycrisp scion.
        - G.935N and G.4814 demonstrated vigor similar to M.26, and meanwhile showed higher cumulative yield efficiency; therefore, they may be better alternatives for weak growing cultivars like Honeycrisp, with good program for root sucker control and crop load management in place.

- G.11 demonstrated similar vigor and cumulative yield with M.9T337. Its resistance to fire blight and tolerance to replanting disease exceeded M.9 in previous reports.

- In the small dwarfing category, G.4003 and B.9 were less vigorous and less productive than M.9T337. To match or exceed the yield per hectare of M.9T337, small dwarfing rootstocks would need to be planted at narrower in-row tree spacing.

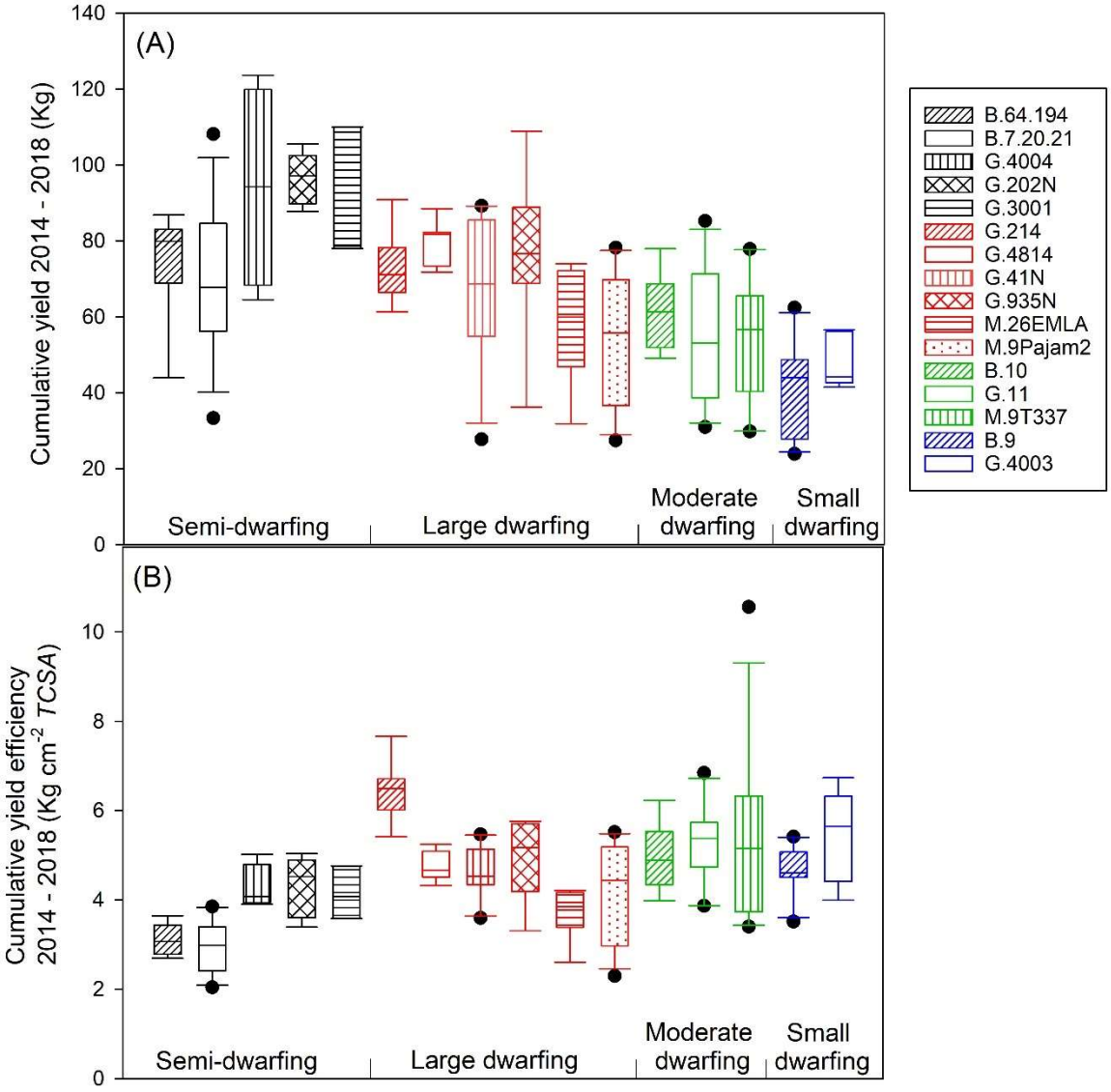

Fig. 2 Cumulative yield **(A)** and cumulative yield efficiency **(B)** of Honeycrisp apple on 16 rootstocks during 2014-2018 in the NC140 2010 trial in Summerland, British Columbia, Canada.

Table 1. Tree vigor and fruit production of Honeycrisp scion on semi-dwarfing and dwarfing rootstocks with reference to M.9T337 in the NC140 2010 Summerland trial.

Vigor Class[1] & reference rootstock[2]		Suggested spacing density[2] (m)	Rootstock	TCSA[3]	Tree height[4]	Canopy width[4]	# of suckers[5]	Zonal chlorosis[6]	Cumulative yield[7]	Cumulative yield efficiency[7]	Projected cumulative yield of 2200 trees per hectare, 1.2 m × 3.7 m (metric ton)
				Compared to M.9T337					Compared to M.9T337		
Semi-dwarfing	Large MM.106	Low 6 X 8.5 Medium 5 X 7.5 High 3.5 X 6	B.7-20-21	235%	125%	150%	11	0.3	125%	55%	153.16
			B.64-194	230%	140%	140%	0	0.3	135%	60%	164.37
	Moderate M.7, V.4	Low 5.5 X 8 Medium 4.5 X 6.5 High 3 X 4.5	G.4004	215%	130%	170%	32	0.3	170%	80%	207.27
			G.202N	215%	130%	165%	64	0.4	175%	80%	212.09
	Small		G.3001	205%	140%	145%	2	0.5	160%	75%	195.78
Dwarfing	Large dwarf M.26	Low 4 X 6 Medium 3 X 5.5 High 2.5 X 4.5	G.214	110%	125%	130%	94	0.5	135%	120%	160.20
			G.41N	150%	125%	145%	8	0.4	130%	85%	148.63
			G.935N	150%	120%	130%	42	0.5	140%	90%	170.24
			G.4814	160%	120%	120%	56	0.6	145%	90%	176.20
			M.9Pajam2	125%	110%	110%	24	0.4	100%	75%	119.64
			M.26EMLA	145%	115%	110%	17	0.4	105%	70%	128.00
	Moderate dwarf M.9	Medium 2.5 X 5 High 1.5 X 3.5	G.11	95%	110%	120%	6	0.5	100%	95%	120.64
			B.10	120%	110%	115%	8	0.4	110%	90%	135.05
			M.9T337	10.6 cm^2	2.6 m	1.3 m	11	0.4	54.8 Kg	5.38 Kg / cm^2	120.63
	Small dwarf B.9	Medium 2.5 X 5 High 1.5 X 3.5	G.4003	85%	105%	90%	3	0.5	90%	100%	106.44
			B.9	85%	95%	85%	34	0.4	75%	85%	90.97

Note: 1. Classification according to Autio et al. 2020; 2. Information retrieved from http://www.treco.nu/products/apple-rootstock/ and Penn State Tree Fruit Production Guide (Accessed on March 23 2019); 3. Data collected in fall 2018; 4. Data collected in fall 2017; 5. Total number of suckers in 2011-2017; 6. Average zonal chlorosis of 2013-2017, 0 for no chlorosis and 1 for 100% chlorosis; 7. Cumulative data during 2014-2018. The scion vigor and fruit production are presented in percentage with reference to the widely used M.9T337; green stands for increase whereas red stands for decrease.

Note: TCSA, tree height and canopy width are important indicators for the vigor of the tree and its capacity to fill the space. Sucker growth and zonal chlorosis are undesirable traits, indicating the disruptions of resource allocation, and, posing challenges to weed and nutrient managements. High cumulative yield and yield efficiency are amongst the most valued production merits in rootstock evaluation.

Table 2. Features of resilience and tolerance of selected rootstocks.

Vigor Class[1]	Rootstock	Origin[2]	Precocity[2]	Resilience and tolerance[2]					
				Cold hardiness	Woolly Aphid	Crown rot (*Phytophthora* spp.)	Fire blight	Replant tolerance	Other features
Semi-dwarf	G.202	Geneva	Yes	Hardy	R	R	R	T	
	CG.3001	Cornell-Geneva	Yes	Hardy					
Dwarf	CG.214	Cornell-Geneva	Yes	Hardy	R	R	R	T	High Calcium in leaves
	G.41	Geneva	Very early	Very hardy	R	R	R	T	Less biennial bearing than M.9
	G.935	Geneva	Yes	Very hardy	S	R	R	T	Inducing wider angled branching in the scion
	CG.4814	Cornell-Geneva	Yes	Hardy	R	R	R	T	Good Calcium supply to scion
	M.9Pajam2	CTIFL, France	Yes	Hardy		R	S	S	
	M.26EMLA	East Malling, Long Ashton	Yes	Hardy	S		S	S	
	G.11	Geneva	Yes	Hardy	S	R	R	T	Less biennial bearing than M.9
	B.10	Budagovski, Russia	Very early	Very hardy		R	R	T	
	M.9T337	East Malling and NAKB Netherlands	Very early	Hardy		R		S	
	B.9	Budagovski, Russia	Very early	Very hardy		R	R	T	Tolerance to apple scab, powdery mildew

Note: R stands for resistant; S stands for susceptible; T stands for tolerant; 1. Classification according to Autio et al. 2020; 2. Norelli et al. 2003, and extension references: http://treefruit.wsu.edu/web-article/apple-rootstocks/; http://www.omafra.gov.on.ca/english/crops/facts/00-007.htm; Cooperative Extension 2020.

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Glossary

Cumulative yield: The sum of annual yield per tree of multiple years.

Cumulative yield efficiency: The sum of annual yield efficiency of multiple years.

Dwarfing rootstock: Dwarfing rootstocks usually produce trees with TCSA of 30-60% of that of a standard seeded tree. According to the vigor of the mature tree, they can be further classified into large, moderate and small.

Projected yield per hectare: An yield estimation in metric ton, which is calculated as yield per tree multiplied by the total number of trees per hectare based on a specific planting density.

Semi-dwarfing rootstock: Semi-dwarfing rootstocks usually produce trees with *TCSA* being about 60% of that of a standard seeded tree.

Trunk cross section area (*TCSA*): An indicator for scion vigor, which is calculated in an approximation of a round disc of trunk cross section, based on the average diameter measured at 30 cm above the grafted union in north-south direction and east-west direction.

Yield efficiency: The kilogram of fruits at harvest per cm^2 of *TCSA* of the tree.

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For more information:

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