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Performance of Three *Pyrus* Pear Rootstocks in Northeastern North America

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Abstract

The adoption of high-density orchards over the past decades has resulted in significant improvements in yield and fruit quality. For pear, however, the lack of precocious rootstocks means that full production is often achieved many years after orchard establishment and remains one of the main challenges in pear production. In 2004, one coordinated rootstock field trial was established at two locations in the USA and Canada. The trials compared three *Pyrus communis* rootstocks: Old Home × Farmingdale (OHF) 97, OHF87 and Pyrodwarf, with 'Taylor's Gold Comice' and 'Concorde' pear as cultivars. After 12 years of growth, trees with OHF97 and OHF87 were the most vigorous under conventional management compared to Pyrodwarf. 'Taylor's Gold Comice' trees on Pyrodwarf rootstocks were 30% smaller than on OHF rootstocks. Cumulative yields were highest from 'Concorde' compared with 'Taylor's Gold Comice'. There were similar values regarding cumulative yield efficiency among the three rootstocks, and fruit size was generally smaller with Pyrodwarf, which also had the most suckers.

The adoption of high-density orchards for pear production over the past few decades has resulted in a significant improvement in early yield and fruit quality (Sansavini et al., 2007). However, full production is often not achieved for several years and remains one of the main challenges when planting a pear orchard. Pear orchards in Northeastern North America were mostly planted on *Pyrus communis* seedling rootstocks, as Quince (*Cydonia oblonga*) rootstocks purportedly suffer from winter injury, fire blight infections, and pear decline (Elkins et al., 2012; Lombard and Westwood, 1987; Wertheim, 2002; Westwood and Lombard, 1983). Since the early 1990s, new pear orchards have been planted on clonal Old Home × Farmingdale (OHF) or other clonal *Pyrus communis* rootstocks (Elkins et al., 2012; Robinson, 2011). OHF series clonal rootstocks result from crosses made in Oregon, and have the advantage of being more size controlling and relatively resistant to fire blight (Azarenko et al., 2002; Westwood and Lombard, 1983). Earlier planted selections (217, 267 and 333) were slow to come into production or produced low yields or small fruit (Mitcham and Elkins, 2007). Other OHF clones (40, 69) have variously demonstrated better precocity or vigor control but require more testing (Mitcham and Elkins, 2007; Wertheim, 1998). In the early 2000's Pyrodwarf, a new Pyrus clonal rootstock from Geisenheim, Germany (Jacob, 1998), was introduced to North America. This clone was reported to produce a tree 65 percent the size of a seedling tree, with higher precocity rates than Quince rootstocks (Jacob, 2002; Lind et al., 2003; Mitcham and Elkins, 2007). Furthermore, yield efficiency has been suggested by some authors to be even more important than precocity and size controlling over the long run (Wertheim, 2002).

The aim of this study was to evaluate and compare the performance of Pyrodwarf to OHF 87 and 97 in cold climates in Northeastern North America. Productivity and fruit size, suckering, tree growth, survival,

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and yield and crop efficiencies were evaluated in two different locations as part of a field trial organized by the NC-140 national project (www.nc140.org). The NC-140 project was originally established to disseminate information generated from uniform trials throughout the United States and Canada. The first pear trial was completed in 1997 (Azarenko et al., 2002), while the last published trial was in 2013 (Einhorn et al., 2013).

Materials and Methods

'Concorde' and 'Taylor's Gold Comice' were grafted onto one-year-old rooted liners of OHF97, OHF87 and Pyrodwarf rootstock at Meadowlake Nursery in McMinnville, Oregon. Trees were grown at the nursery for one year prior to being shipped in the spring of 2004 to the trial sites. In 2004, 10 single-tree replicates of each scion x rootstock combination were planted at the New York State Agricultural Experiment Station in Geneva, New York, USA (lat. 42.9°N, long. 77.0°W), and 5 replicates were planted at a commercial site in Rockland, Nova Scotia, Canada (lat. 45.0°N and long. 64.7°W). For Geneva, the soil was a Honeoye fine sandy loam (He), with good water holding capacity, well drained and fertile with about 3% organic matter content. In Rockland, soil was a combination of Berwick (B) and Millar (Mr) soils characterized as sandy loam till derived from sandstone and dark gray sand over gleyed gray sand. Trials at both sites were not irrigated and relied upon natural rainfall for moisture.

Trees were planted in April in a randomized complete block design with blocking by initial tree diameter and with a tree spacing of 2.5 m x 4.5 m. Trees were trained as central leaders with two tiers of branches, with branches spread to 70-90° from vertical in the third year. Both sites were managed with conventional pesticides and fertilizers according to industry standards. Data were collected from 2004-2015 at both sites, variables recorded annually included: tree survival (%), trunk circumference measured 30 cm above graft union (cm), fruit number and yield (kg), and number of root suckers (suckers were counted each year and then removed). Trunk-cross-sectional area (TCA, cm^2), crop efficiency (no. fruit/cm^2), yield efficiency (kg/cm^2), and fruit size were then calculated. Response variables were modeled using linear mixed effect models. A first analysis was carried out using block nested in site as random factor (Table 1). Subsequent analyses were performed taking into account significance of interactions (Table 1). All mean separations were performed by

Table 1. Results (*P* values) from initial mixed models that included site, cultivar, rootstock and their respective interactions as fixed factors, with block nested in site as a random factor to evaluate treatment effects.

Factor	Final TCA (cm^2)	Cum Yield (kg)	Cum Fruit Number	Cum yield eff (kg/cm^2)	Cum crop eff (#/cm^2)	Av fruit size (g)	Survival %	Cum Root Suckers
Site	0.2646	0.1158	0.0151	0.1347	0.0103	0.0041	0.3830	<.0001
Cultivar	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.1016	0.0102
Site*Cultivar	0.0122	0.1260	0.7509	0.5229	0.1737	0.1007	0.1016	0.3203
Rootstock	<.0001	0.0040	0.0229	0.3680	0.6240	<.0001	0.8464	<.0001
Site*Rootstock	0.5398	0.1639	0.0590	0.0233	0.0052	0.0600	0.8464	0.0068
Cultivar*Rootstock	0.0010	0.1290	0.0742	0.4320	0.2719	0.0135	0.8464	0.3131
Site*Cultivar*Rootstock	0.1917	0.4818	0.2588	0.2319	0.0711	0.0173	0.8464	0.5808

LSD $P \leq 0.05$. Data were analyzed using the JMP statistical software package (Version 11; SAS Institute Inc., Cary, North Carolina).

Results

Yield, fruit number, and survival. 'Concorde' produced significantly higher yields and more number of fruits than 'Taylor's Gold Comice' (Fig. 1). Similar yields and number of fruits were observed for both OHF rootstocks, whereas Pyrodwarf had lower values than OHF97 (Fig. 1). No significant differences regarding tree survival were observed within cultivars and rootstocks (Table 1).

Tree vigor and fruit size. At Geneva, 'Taylor's Gold Comice' trees were significantly larger than 'Concorde' after 12 years of growth, with OHF87 and OHF97 producing larger trees than Pyrodwarf for both cultivars (Table 2). There was a significant interaction between rootstock and scion at Rockland. Larger trees were 'Taylor's Gold Comice' on OHF rootstocks, whereas the smallest ones were 'Taylor's Gold Comice' on Pyrodwarf and 'Concorde' on OHF87 and Pyrodwarf (Table 2).

Regarding fruit size, there was a significant cultivar x rootstock interaction at Gene-

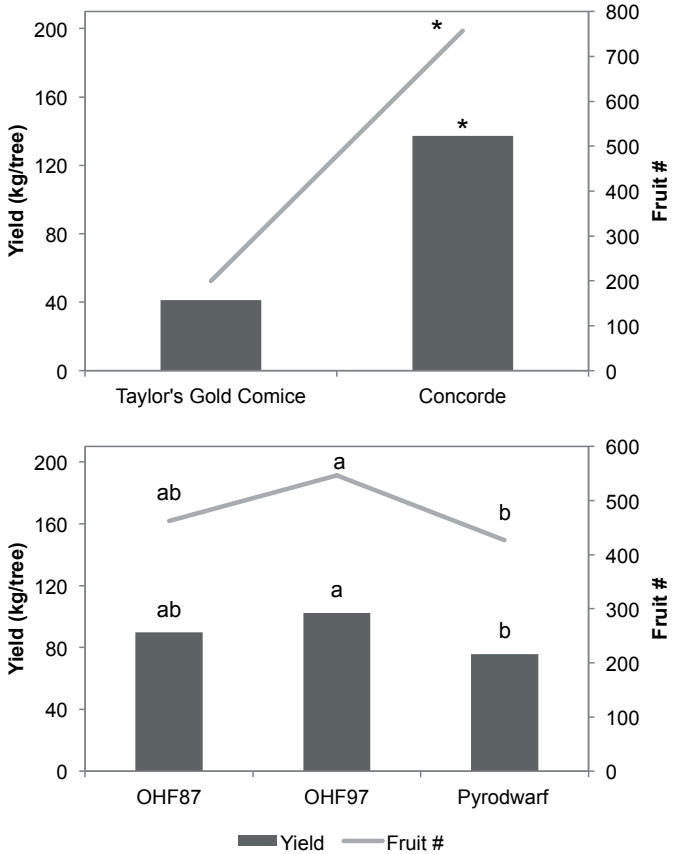

Fig. 1. Cumulative yield (kg) and fruit number per tree (2004-2015) for 'Concorde' and 'Taylor's Gold Comice', and for OHF87, OHF97, and Pyrodwarf rootstocks. Different letters indicate significant differences at $P = 0.05$ using LSD.

Table 2. Final trunk cross sectional area (TCA) and average fruit size (2004-2015) for 'Concorde' and 'Taylor's Gold Comice' on *Pyrus* rootstocks in Geneva (NY) and Rockland (NS) orchards.

Site	Cultivar	Rootstock	TCA (cm^2)	Fruit size (g)
Geneva, NY	'Concorde'	OHF87	146 ab[z]	204 c
		OHF97	156 a	189 d
		Pyrodwarf	125 b	184 d
		LSD *P*≤0.05	**26**	
	'Taylor's Gold Comice'	OHF87	218 a	223 b
		OHF97	216 a	238 a
		Pyrodwarf	164 b	211 bc
		LSD *P*≤0.05	**25**	
	Cultivar		***	***
	Rootstock (LSD *P*≤0.05)		***	**
	Cultivar*Rootstock (LSD *P*≤0.05)		**NS**	**14**
Rockland, NS	'Concorde'	OHF87	137 c	178 ab
		OHF97	161 bc	190 a
		Pyrodwarf	141 c	170 b
		LSD *P*≤0.05		**16**
	'Taylor's Gold Comice'	OHF87	192 ab	219
		OHF97	209 a	214
		Pyrodwarf	119 c	145
		LSD *P*≤0.05		**NS**
	Cultivar		*	**NS**
	Rootstock (LSD *P*≤0.05)		**	*
	Cultivar*Rootstock (LSD *P*≤0.05)		**67**	**NS**

[z] Within a column, means followed by the same letter are not statistically significant at $P = 0.05$ using LSD. [NS], *, **, *** Non significant or significant at $P = 0.05$, 0.01 or 0.001, respectively.

va. Larger fruit sizes were observed for 'Taylor's Gold Comice' on OHF97, followed by OHF87, Pyrodwarf, 'Concorde' on OHF87, and the smallest fruits with 'Concorde' on both OHF97 and Pyrodwarf (Table 2). At Rockland, no significant differences between cultivars and within 'Taylor's Gold Comice' were observed, whereas for 'Concorde', smallest fruits were on Pyrodwarf (Table 2).

Yield efficiency, crop efficiency, and suckering. Cumulative yield and cumulative crop efficiency were significantly highest for 'Concorde' over the life of the study (Fig. 2). On the other hand, less amount of suckers were observed with 'Taylor's Gold Comice'. There was a significant site x rootstock interaction for cumulative yield efficiency, crop efficiency, and number of suckers (Table 1). Lower cumulative yield efficiency was observed for Pyrodwarf at Rockland (Fig. 2). Regarding crop efficiency, highest values were observed for OHF at Geneva and OHF87 at Rockland, whereas the lowest indexes were on OHF97 and Pyrodwarf at Rockland (Fig. 2). Pyrodwarf at Geneva had significantly higher amount of suckers, whereas OHF tended to sucker less, especially at Rockland (Fig. 2).

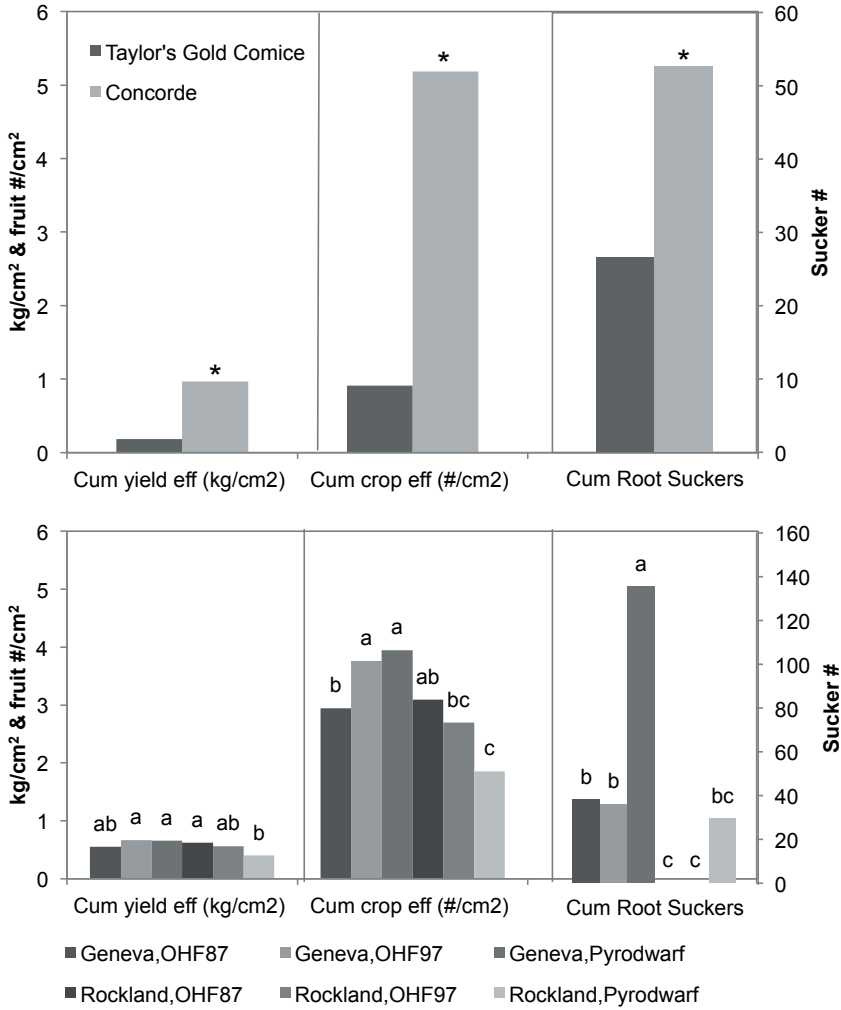

Fig. 2. Cumulative yield efficiency (kg·cm^{-2}) cumulative crop efficiency (Number of fruits per cm^{-2}), and cumulative number of root suckers at Geneva NY and Rockland NS on OHF87, OHF97, and Pyrodwarf rootstocks. Different letters indicate significant differences at $P = 0.05$ using LSD.

Discussion

Yield, fruit number, and survival. Higher cumulative yields were observed for 'Concorde' compared to 'Taylor's Gold Comice'. Regarding rootstocks, Pyrodwarf yields were lower, with no differences between the two OHF rootstocks. Similar results were also observed with 'd'Anjou' and 'Golden Russet Bosc' in the Pacific Northwest (PNW) (Einhorn et al., 2013). Other studies, have reported slightly higher cumulative yields for OHF87 versus OHF97 (Elkins et al., 2011; Ing, 2002; Robinson, 2008; Westwood et al., 1976), most likely due to its dwarfing behavior and precocity. Unfortunately, we did not assess bloom and fruit setting over time to correlate it with yield precocity in our study. Some 'Concorde' trees at the Geneva site

were affected by fireblight, but neither rootstock nor variety had a significant effect in tree survival in our study.

Tree vigor and fruit size. No significant differences in tree size were observed in our study between OHF87 and OHF97 rootstocks. OHF97 has been reported to be a more vigorous rootstock than the semi-dwarf OHF87 (Mitcham and Elkins, 2007; Westwood, 1993; Westwood and Lombard, 1983) in most studies. Robinson (2008), however, found the opposite with 'Taylor's Gold Comice' where OHF87 trees were significantly larger than OHF97 trees in Geneva NY.

While trees on Pyrodwarf were the smallest in our study, other trials in the (PNW) USA, reported no significant differences in vigor between Pyrodwarf and OHF87 (Einhorn et al., 2013). In Germany, Pyrodwarf was observed to be 40% weaker than Fox 11 (Jacob, 2002), and Fox 11 was reported to be smaller than OHF87 and Pyrodwarf in the PNW (Einhorn et al., 2013).

In general, fruit size in our study was smaller on Pyrodwarf, consistent with results obtained for 'Golden Russet Bosc' and 'd'Anjou' (Einhorn et al., 2013).

Cumulative yield efficiency, cumulative crop efficiency, and suckering. Cumulative efficiencies were low for 'Taylor's Gold Comice', suggesting that this cultivar might not be the most appropriate for cold areas like Northeastern North America. However, there is a dearth of data regarding the effect of temperature on performance of this cultivar in northern latitude growing areas. Some authors reported that will set light crops in wetter climates, i.e. some regions of the Pacific Northwest (Mitcham and Elkins, 2007). Similar cumulative yield efficiency values were observed for OHF and Pyrodwarf rootstocks, with the only significant difference for Pyrodwarf at Rockland, which had the lowest index. Furthermore, Pyrodwarf rootstocks tended to produce more suckers. In contrast, low suckering habits were observed for Pyrodwarf in other studies (Jacob, 2002; Jacob, 1998).

The results from this study with Pyrodwarf are similar to published results from other North American trials (Elkins et al., 2011; Robinson, 2008). Einhorn et al. (2013) reported Pyrodwarf to have low cumulative yield efficiency, producing low yields and smaller fruit size for both 'd'Anjou' and 'Golden Russet Bosc'. On the other hand, OHF87 was reported to be the best rootstock in the PNW, with high cumulative yield efficiency and large fruit size (Einhorn et al., 2013). This experiment confirms that in Northeastern North America, Pyrodwarf has similar or poorer yield, smaller fruit size and more suckers than OHF 87 or 97 while offering no greater dwarfing or yield efficiency.

Conclusions

Under conventional management, OHF97 and OHF87 produced larger trees than Pyrodwarf. 'Taylor's Gold Comice' trees on Pyrodwarf were 30% smaller than trees on either OHF rootstock. Cumulative yield generally reflected tree size with OHF rootstocks having the highest yields. Yield efficiency was similar for all three rootstocks, and fruit size was generally smaller for Pyrodwarf rootstocks, which also produced the most suckers. Based on the results obtained here, Pyrodwarf does not offer any significant advantage over OHF for new pear orchards planted in Northeastern North America.

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