

EVALUATION OF POTENTIAL NEW, SIZE CONTROLLING ROOTSTOCKS FOR EUROPEAN PEARS

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ABSTRACT

The Multi-State Research Project NC-140, "Improving Economic and Environmental Sustainability in Tree Fruit Production Through Changes in Rootstock Use", was established in the late 1980s. The first 10-year, multi-state pear trial was established in 1987 and subsequent ones in 2004-2006. Three trials were planted in California in April 2005: Bartlett in Mendocino (loam) and Sacramento (clay) Counties and 'Golden Russet' Bosc in Mendocino County (loam). Trial design was the standard NC-140 configuration of randomized complete block (RCB) with 10 single tree replicates. Rootstocks included 708-36 (United Kingdom), BM 2000 (Australia), Fox 11 (Italy), Horner 4 (Oregon), OHxF 69 (Oregon) (Mendocino Bartlett only), OHxF 87 (Oregon), Pyro-233 and Pyrodwarf (both Germany). The Sacramento trial was abandoned after 2009, and the final trial data presented in the 2010 report. Survival rate in Mendocino County ranges from 60-100%, with Fox 11 having the most losses. In 2012, Bartlett yields decreased 20% from 2011. Horner 4 were the largest trees and 708-36 the smallest. Horner 4 had the largest and most fruit and yielded the most. 708-36 had the smallest fruit. There were no differences in yield efficiency. For Bosc, Horner 4 trees were largest and 708-36, OHxF 87 and Pyro 2-33 the smallest. BM 2000 had the largest fruit and 708-36 the smallest. There were no differences in number of fruit, yield, or yield efficiency. Pyrodwarf and OHxF 87 had the highest soluble solids and Horner 4 the lowest. OHxF 87 fruit was firmest. 2012 was the eighth season of the 10 year trial; data collection will continue through 2014. Two new non-NC140 but related rootstock trials were established in spring 2012 in Marysville, Yuba County, CA (fine sandy loam): six cultivars on three *Amelanchier* (serviceberry) clones and Quince 'Eline' (all from Germany) and Bartlett on three OHxF clones (69, 87, 97).

INTRODUCTION AND OBJECTIVES

There are very few commercially viable size controlling rootstocks for pear. Quince rootstock is widely used in Europe interstemmed with Old Home or Beurre Hardy, but is only being employed in the U.S. as a rootstock for Comice due to its incompatibility with other cultivars. The Old Home x Farmingdale (OHxF) (Brooks®) series offers several potential options that have only recently been re-explored. The two OHxF selections currently most offered by major wholesale nurseries are 97 and 87 (333 is generally sold to homeowners). 97 is a large tree similar to Winter Nelis, though more precocious than *P. betulaefolia*). 87 is a smaller tree, but has been shown to produce small fruit in some locations. Data from California, and more recently Washington, has suggested that OHxF 69, which has limited commercial availability, may also be promising,

particularly for Bosc, but is difficult to propagate by hardwood cuttings (Elkins and DeJong, 2002; Elkins et al., 2008; Elkins and DeJong, 2011; Elkins, Bell and Einhorn, 2012).

The NC-140 Regional Rootstock Research Project (www.NC140.org) is a federally-supported, multi-state project for perennial fruit and nut crops. The goal is to disseminate information generated from long-term (generally 10 year) trials throughout the U.S. Each participating state (as well as Canada and Mexico) establishes and evaluates similar ("uniform") trials using the same rootstocks and similar plot design so that regional differences can be determined. Researchers share progress and results at the annual meeting and via the NC-140 website. Each state representative submits an annual report which is distributed at the meeting and then compiled into a national report for USDA and posted on the NC-140 website for public use. Data is also shared with nurseries and growers who can then select rootstocks suitable to their location and customer base. California began participating in NC-140 for apples in 1995 and peaches in 2001 and began participating actively in pears in 2005.

In coordination with Oregon, Washington, New York, and Chihuahua, Mexico, three NC-140 trials were established in California in spring 2005: two in Talmage, Mendocino County (Bartlett and 'Golden Russet' Bosc, 5' x 10' spacing), and one in Courtland, Sacramento County (Bartlett, 9' x 15' spacing). Rootstock liners were propagated by Meadow Lake Nursery, McMinnville, Oregon then budded and grown by Fowler Nurseries, Inc., Newcastle, California. The Courtland trial was abandoned after 2009, leaving the two Mendocino County trials in place. Rootstock and cultivar selections for the existing 2005 NC-140 pear plantings are shown in Table 1.

The NC-140 trials are currently the only **bearing replicated** rootstock trials in California and the Talmage Bartlett trial is the only one planted in 2005 that includes OHxF 69. In addition to the NC-140 trials, two new "unofficial" but related trials were planted in 2012 in Marysville, California. The first is actually a group of six replicated trials, each comparing one of six cultivars (Bartlett, 'Golden Russet' Bosc, BPM, Comice, Forelle, and 'Super Red' (aka Starkrimson)) on three German selections (A2, A7, A10) of serviceberry (*Amelanchier* spp.) along with Quince Eline. The second trial is comparing Bartlett on OHxF 69, OHxF 87, and OHxF 97. These trials are planted contiguously in fine sandy loam.

The ultimate objective of the above trials, as with all NC-140 and other rootstock trials, is to select the best potential available candidates for future increased propagation and industry use. The information they provide will contribute to future nursery and grower planting decisions, particularly for new, high density planting systems. The 2012 continuing objective of the Talmage NC140 trial was to evaluate rootstocks for size, vigor, growth habit, productivity, compatibility with major varieties, susceptibility to diseases and pests, propensity to sucker, etc. The objective of the new 2012 *Amelanchier* and Quince 'Eline' trial is to test interspecific compatibility. The objective of the new OHxF trial is to gain further comparative data among the three most widely-known OHxF clones.

PROCEDURES

2005 NC-140 Regional Rootstock Trial - Two trials were planted in Talmage (Ukiah Valley), Mendocino County, California in April 2005. Design was randomized complete block, with 10 single tree replicates per rootstock. Data collection and calculation from 2005-2012 included number of flower clusters (2005-2010), number of fruit, tree height, trunk cross sectional area (TCSA), yield, yield efficiency, number of root suckers, and % survival. 2010-2012 data also included firmness (kg) and soluble solids (°Brix).

2012 Amelanchier spp. and Quince 'Eline' and OHxF clones - Six side-by-side replicated trials consisting of one cultivar on each of four rootstocks were planted in March 2012 on Columbia fine sandy loam soil along the Yuba River in Marysville, California. This trial will be compared to a contiguous replicated planting of Bartlett on several Old Home x Farmindeale clones (OHxF 69, 87, and 97) to the immediate north on the same soil and under the same management but planted in May 2012. Design is RCB with five single tree replicates (total of four trees per rep), for a total of 30 trees per rootstock (A2, A7, A10 and Quince Eline). There is thus a total of 180 trees (30 per cultivar).

Both trials were planted 4' x 20' oriented north to south on berms, irrigated with microsprinklers, and are being trained into an "informal" perpendicular "V". Survival and growth data (caliper and number of shoots) will commence in winter 2012.

RESULTS AND DISCUSSION

2005 Bartlett Pear Rootstock Planting

2012 results (Tables 2-3)

No trees were lost in 2012. Overall fruiting decreased 26% but fruit size increased 8%, though it generally remained small for most rootstocks. Tree yield decreased 20% commensurate with the statewide average. Horner 4 continued to have the most and largest fruit, greatest yield, and yield efficiency equal to the other rootstocks. 708-36 had the smallest fruit. TCSA increased 19% from 2011, with Horner 4 being the largest and OHxF 87 and 708-36 the smallest trees. Yield efficiency was lower than 2011 due to lower yields decreased but there were no differences among rootstocks. BM 2000 had the most root suckers. Unlike 2011, there were significant differences in fruit firmness and soluble solids in 2012. 708-36 had the firmest fruit and Horner 4 the lowest sugars.

2005-2012 cumulative results (Table 4)

Tree survival – There were no significant differences in tree survival.

Fruit size – Average fruit size has been relatively small, ranging from 159-189 grams. From 2009-2011, the late growing seasons may have reduced growing time. Fundamentally, however, most of these rootstocks have also been selected for lower vigor and fruit thinning (not normally practiced in California) and more intensive practices may be required to enable large fruit in some cases. Horner 4 has had the largest fruit thus far (189 grams average), while 708-36, OHxF 69, and OHxF 87 the smallest.

Tree size and vigor – After eight seasons, Horner 4 trees are nearly twice as large as others, followed by BM 2000, Fox 11, OHxF 69, and Pyro 2-33 (these three are the same size), Pyrodwarf, OHxF 87, and lastly, 708-36 (the smallest).

Cumulative yield and yield efficiency – Horner 4 has yielded over twice as much as the next highest yielding rootstocks, BM 2000 and Pyrodwarf. 708-36 has yielded the least and all others equally. There are fewer differences in yield efficiency, with Pyrodwarf, Horner 4, and OHxF 87 having the highest and OHxF 69 the lowest efficiency due to poor yields relative to tree size, in contrast with past results with ‘Golden Russet’ Bosc (Elkins and DeJong, 2011) and data from other locations (Auvil, 2005) and may be related to scion or that some OHxF 69 trees have expressed poor vigor, bark cracking, and dieback of as-yet undefined origin at this location. Low vigor due to lack of juvenility, a known characteristic attributed to some clonal rootstocks, is one possible cause being currently being addressed by industry-supported research on improving micropropagated rooting and growth (Reed 2011). OHxF 69 liners readily flower soon after planting in the nursery, suggesting lack of juvenility, which may in turn, reduce grafted tree vigor. The new high density trial in Marysville, California should further illuminate this situation by ascertaining how well OHxF 69 grows in relation to OHxF 87 and 97. Interestingly however, OHxF 69 yield and fruit size have equaled OHxF 87 in this trial, and OHxF 69 trees are larger than OHxF 87.

Root suckers – There have been very few root suckers at this location. Only Fox 11 and BM 2000 have had two or more, although OHxF 69 had 1.9. Neither Pyrodwarf nor Pyro 2-33 have suckered, in contrast with profuse suckering of Pyrodwarf in other locations (Washington, New York).

2005 ‘Golden Russet’ Bosc Pear Rootstock Planting

2012 results (Tables 5-6)

Overall survival is less than in the Bartlett trial with no changes in 2012. The number of fruit and yield decreased by 49% from 2011, reflecting Bosc’s tendency to alternate bear. Overall fruit size increased by 2%. Only fruit size, trunk cross-sectional area, and

tree height differed significantly. BM 2000 had the largest fruit and 708-36 the smallest. Horner 4 had the largest trunk cross-sectional area and Pyro 2-33, OHxF 87 and 708-36 the smallest. There were few root suckers. OHxF 87 had the firmest fruit. Soluble solids were highest for OHxF 87 and Pyrodwarf and lowest for Horner 4.

2005-2011 cumulative results (Table 7)

Tree survival – Horner 4 is the only selection with 100% survival, although there were no statistical differences among rootstocks.

Fruit size – There have been no differences among rootstocks. Average fruit size has been small, suggesting overall low vigor, likely for the same reasons as described above for Bartlett.

Tree size and vigor – As with Bartlett, Horner 4 trees are the largest, but there are fewer differences among selections than for Bartlett. This may be related to the relatively low crop load on the Bosc versus Bartlett trees as well as significant variability among replicates. 708-36, OHxF 87, and Pyro 2-33 are the smallest trees.

Cumulative yield and yield efficiency – Overall yields have been about half those of Bartlett and there are no significant differences among rootstocks. OHxF 87 has the highest yield efficiency relative to other rootstocks due to its small size, while Horner 4 has the lowest due to its greater vigor. OHxF 69 was not included in the Bosc trial so cultivar performance cannot be compared with Bartlett.

Root suckers – There have been no difference among rootstocks.

WORK PLANNED FOR 2013 (Year 9) – Data collection and rootstock evaluation will continue through 2014. Procedures will again follow guidelines established by the NC140 Technical Committee. Data on the new *Amelanchier*/Quince ‘Eline’ and new OHxF 69, 87, and 97 trial in Marysville will also be taken and summarized.

ACKNOWLEDGEMENTS

Thanks to cooperators Chris and Matt Ruddick (Talmage) and John Callis and Balthazar Teyes of Naumes (Marysville); Chuck Fleck and John Ireland of Fowler Nurseries, Inc., Newcastle, and Dave Weil (Tree Connection/Varieties International) for growing and shipping trees and for their valuable advice; Steve Castagnoli, Todd Einhorn and Gene Mielke, Oregon State University, for initial and continuing NC104 trial coordination and collaboration; and Michael Brown, Nicole Gentry, Sarah Johnson, Jim Nosera, Gabriele O’Neill, Makaila Rodrigues, and Carolyn Shaffer for field assistance and data summarization and presentation.

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Table 1: Locations and included rootstocks, current 2005 NC140 Bartlett and Bosc¹ pear rootstock trials.

Rootstock	Origin	CA1	CA2 ²	CH (MX)	NY	WA
708-36	United Kingdom	Bart, Bosc	Bart	-	Bart, Bosc	-
BM 2000	France	Bart, Bosc	Bart	Bart	Bart	Bosc
Fox 11	France	Bart, Bosc	Bart	-	Bart	-
Horner 4	Oregon	Bart, Bosc	Bart	-	Bart, Bosc	Bosc
OHxF 69	Australia	Bart	-	-	-	-
OHxF 87	Germany	Bart, Bosc	Bart	Bart	Bart	Bosc
OHxF 97	Germany	-	-	-	-	-
Pyrodwarf	Italy	Bart, Bosc	Bart	Bart	Bart, Bosc	Bosc
Pyro 2-33	Hood River, OR	Bart, Bosc	Bart	-	Bart	Bosc
Winter Nelis	Oregon	-	Bart	-	-	-
BU-3	Oregon	-	-	-	-	Bosc

¹ Three Anjou trials in Oregon and Washington are not included in this table.

² CA2 was disbanded in 2009.

Table 2: Effects of 2005 NC-140 rootstock planting on flower clusters, number and size of fruit, tree yield, trunk cross-sectional area, root suckers and tree survival among 7-year-old (8th leaf) Bartlett pear trees, Talmage, California, 2012.

	No. Fruit 8/21/12 (no./tree)	Fruit Size 8/21/12 (g/fruit)	Yield 8/21/12 (kg/tree)	TCSA 10/12/12 (cm ²)	Yield Efficiency 10/12/12 (kg/cm ²)	Tree Height 10/12/12 (cm)	Root Suckers ³ 10/12/12 (no./tree)	Tree Survival 8/21/12 (%/10 trees)
ROOTSTOCK ¹								
708-36	70 b	158 b	10.5 b	21.6 d	0.46	221 c	0.1 ab	90
BM 2000	95 b	196 ab	18.2 b	37.2 b	0.50	254 ab	1.4 a	100
Horner 4	159 a	204 a	32.1 a	58.3 a	0.55	261 a	0.1 b	100
Fox 11	73 b	183 ab	13.0 b	32.2 bc	0.41	239 abc	0.8 ab	80
OHxF 69	81 b	181 ab	14.4 b	34.0 bc	0.41	232 bc	0.0 b	90
OHxF 87	77 b	168 ab	12.6 b	26.5 cd	0.48	228 c	0.0 b	100
Pyrodwarf	89 b	179 ab	15.7 b	29.5 bcd	0.54	236 abc	0.2 ab	90
Pyro 2-33	76 b	198 ab	13.8 b	31.2 bc	0.45	236 abc	0.0 b	70
ANOVA ²								
Rootstock	*** (<0.001)	** (0.01)	*** (<0.001)	*** (<0.001)	NS (0.37)	*** (<0.001)	* (0.05)	-----
Block	NS (0.44)	* (0.03)	NS (0.75)	* (0.03)	NS (0.82)	* (0.02)	NS (0.16)	-----

¹ Within columns, rootstock treatment means significantly different (Tukey HSD test, $P \leq 0.05$).

² *, **, *** Indicate significance at $P \leq 0.05$, 0.01, and 0.001 respectively. NS indicates not significant.

³ Root sucker data normalized using SQRT (root sucker +1), P-value ≤ 0.05 (Duncans Multiple Range Test).

Table 3. Effects of 2005 NC-140 rootstock planting on firmness and soluble solids among 7-year-old (8th leaf) 'Bartlett' pear trees, Talmage, California, 2012.

	Firmness 8/30-31/12 (kg force)	Soluble Solids 8/30-31/12 (°Brix)
ROOTSTOCK ¹		
708-36	7.9 a	15.1 ab
BM 2000	7.3 ab	13.7 b
Horner 4	6.9 b	13.7 b
Fox 11	7.4 ab	15.2 a
OHxF 69	7.7 ab	15.6 a
OHxF 87	7.4 ab	15.0 ab
Pyrodwarf	7.6 ab	15.6 a
Pyro 2-33	7.6 ab	14.0 ab
ANOVA ²		
Rootstock	* (0.03)	** (0.01)
Block	** (0.01)	NS (0.63)

¹ Within columns, rootstock treatment means significantly different (Tukey HSD test, $P \leq 0.05$ [firmness] and 0.10 [soluble solids]).

² *, ** Indicate significance at $P \leq 0.05$ and 0.01 respectively. NS indicates not significant.

Table 4: Cumulative effects (2005-2012) of 2005 NC-140 rootstock planting on tree survival, average fruit size, tree yield, trunk cross-sectional area, yield efficiency, and root suckers of 7-year-old (8th leaf) Bartlett pear trees, Talmage, Mendocino County, California.

	Tree Survival (%/10 trees)	Average Fruit Size ³ (g/fruit)	Average Cumulative Yield (kg)	2012 TCSA (cm ²)	Average Cumulative Yield Efficiency ⁴ (kg/cm ²)	Root Suckers ⁵ (cum. no./tree)
ROOTSTOCK¹						
708-36	90	159 c	37.2 c	21.6 e	1.68 ab	0.3 ab
BM 2000	100	173 abc	64.5 b	37.2 b	1.75 ab	2.7 ab
Horner 4	100	189 a	114.4 a	58.3 a	1.97 a	0.2 ab
Fox 11	80	178 abc	55.5 bc	32.2 bc	1.75 ab	3.1 a
OHxF 69	90	157 c	49.2 bc	34.0 bc	1.40 b	1.9 ab
OHxF 87	100	161 c	51.2 bc	26.5 de	1.95 a	0.3 ab
Pyrodwarf	90	162 bc	61.5 b	29.5 cde	2.11 a	0.0 b
Pyro 2-33	70	185 ab	54.2 bc	31.2 bc	1.71 ab	0.0 b
ANOVA²						
Rootstock	NS (0.28)	*** (<0.001)	*** (<0.001)	*** (<0.001)	** (0.003)	** (0.005)
Block	NS (0.56)	** (0.005)	** (0.002)	* (0.03)	NS (0.10)	NS (0.27)

¹ Within columns, rootstock treatment means significantly different (Tukey HSD test, $P \leq 0.05$).

² *, **, *** Indicate significance at $P \leq 0.05$, 0.01, and 0.001 respectively. NS indicates not significant.

³ Average fruit size based on fruiting years – 2008 to 2012

⁴ Based on cumulative yield (2005-2012) and final TCSA (2012).

⁵ Root sucker data normalized using SQRT (root suckers + 0.5), $P \leq 0.05$ (Duncan Multiple Range Test).

Table 5. Effects of 2005 NC-140 rootstock planting on number and size of fruit, tree yield, trunk cross-sectional area, yield efficiency, tree height, root suckers and tree survival among 7-year-old (8th leaf), 'Golden Russet' Bosc pear trees, Talmage, California, 2012.

	No. Fruit 9/13/12 (no./tree)	Fruit Size 9/13/12 (g/fruit)	Yield 9/13/12 (kg/tree)	TCSA 10/12/12 (cm ²)	Yield Efficiency 10/12/12 (kg/cm ²)	Tree Height 10/12/12 (cm)	Root Suckers ³ 10/12/12 (no./tree)	Tree Survival 9/13/12 (%/10 trees)
ROOTSTOCK¹								
708-36	57	141 c	7.8	34.5 b	0.24	245 ab	0.2 ab	80
BM 2000	42	193 a	8.1	48.8 ab	0.18	253 ab	0.7 a	70
Horner 4	42	173 ab	7.2	62.0 a	0.13	260 a	0.2 ab	100
Fox 11	50	183 ab	8.7	48.6 ab	0.20	248 ab	0.0 b	60
OHxF 87	55	149 bc	8.2	37.9 b	0.23	228 b	0.0 b	80
Pyrodwarf	54	163 abc	8.7	46.4 ab	0.20	241 ab	0.0 b	90
Pyro 2-33	59	157 bc	9.2	42.4 b	0.23	233 b	0.0 b	80
ANOVA²								
Rootstock	NS (0.68)	***(<0.001)	NS (0.94)	** (0.002)	NS (0.15)	** (0.003)	NS (0.17)	-----
Block	NS (0.44)	** (0.0003)	NS (0.41)	* (0.02)	NS (0.29)	NS (0.32)	NS (0.78)	-----

¹ Within columns, rootstock treatment means significantly different (Tukey HSD test, $P \leq 0.05$).

² *, **, *** Indicate significance at $P \leq 0.05$, 0.01, and 0.001 respectively. NS indicates not significant $P \leq 0.05$.

³ Root sucker data normalized SQRT (root sucker + 1), $P \leq 0.05$. (Duncan Multiple Range Test).

Table 6. Effects of 2005 NC-140 rootstock planting on firmness and soluble solids among 7-year-old (8th leaf) 'Golden Russet' Bosc pear trees, Talmage, California, 2012.

	Firmness 9/14/12 (kg force)	Soluble Solids 9/14/12 (°Brix)
ROOTSTOCK¹		
708-36	7.7 ab	14.3 ab
BM 2000	7.9 ab	14.6 ab
Horner 4	7.5 b	14.0 b
Fox 11	7.3 b	14.4 ab
OHxF 87	8.9 a	15.6 a
Pyrodwarf	7.7 ab	15.6 a
Pyro 2-33	7.0 b	15.3 ab
ANOVA²		
Rootstock	** (0.01)	** (0.01)
Block	*** (0.001)	NS (0.07)

¹ Within columns, rootstock treatment means significantly different (Tukey HSD test, $P \leq 0.05$).

² **, *** Indicate significance at $P \leq 0.01$, and 0.001 respectively. NS indicates not significant.

Table 7. Cumulative effects (2005-2012) of 2005 NC-140 rootstock planting on tree survival, trunk cross-sectional area, tree yield, average fruit size, yield efficiency, and root suckers of 7-year-old (8th leaf) 'Golden Russet' Bosc pear trees, Talmage, Mendocino County, California.

	Tree Survival (%/10 trees)	Average Fruit Size ³ (g/fruit)	Average Cumulative Yield (kg)	2012 TCSA (cm ²)	Average Cumulative Yield Efficiency ⁴ (kg/cm ²)	Root Suckers ⁵ (cum.no./tree)
ROOTSTOCK¹						
708-36	80	150	27.1	34.5 b	0.75 ab	0.4
BM 2000	70	140	15.6	48.8 ab	0.36 bc	1.5
Horner 4	100	169	19.5	62.0 a	0.33 c	1.5
Fox 11	60	157	22.4	48.6 ab	0.45 abc	0.3
OHxF 87	80	171	32.6	37.9 b	0.80 a	0.0
Pyrodwarf	90	172	23.1	46.4 ab	0.51 abc	0.0
Pyro 2-33	80	147	17.9	42.4 b	0.44 abc	0.0
ANOVA²						
Rootstock	NS (0.41)	NS (0.35)	NS (0.21)	** (0.002)	*** (0.001)	NS (0.39)
Block	NS (0.43)	NS (0.12)	NS (0.71)	** (0.01)	NS (0.97)	NS (0.64)

¹ Within columns, rootstock treatment means significantly different (Tukey HSD test, $P \leq 0.05$).

² **, *** Indicate significance at $P \leq 0.01$, and 0.001 respectively. NS indicates not significant.

³ Average fruit size based on fruiting years – 2008 to 2012.

⁴ Based on cumulative yield (2005-12) and final TCSA (2012).

⁵ Root sucker data normalized SQRT (root sucker + 1), $P \leq 0.05$ (Duncan Multiple Range Test).